PUBLISHER'S COLUMN

'COMPUTERS 1959'

Included in this issue is a rather special data sheet on digital and analogue computers. We felt that all the information about these instruments should be printed on *one* piece of paper and that it should be easily detachable from the magazine. So the size of the paper had to become very large—in fact 36″ × 24″.

To relieve and help classify the intricate mass of figures we decided that it was necessary to print in other colours than black—and in fact two further colours were chosen. In order to reduce its size so that it physically fitted the magazine four different folds had to be made.

In all, these various operations have added very considerable costs to the production of this particular issue. We committed ourselves to this expense as an act of faith—believing that the information was best presented in this way and that individual engineers and firms might wish to buy extra copies.

We were, apparently, quite right in our judgment. For even before publication thousands of extra copies had been ordered and will be displayed all over the world. And if you would like extra copies of 'Computers 1959' send us 2s. 6d. or equivalent in your currency for each copy and we will despatch immediately to you.

THE BEST JOBS IN CONTROL

Why has there been such an enormous growth of our classified columns over the five months of this magazine's life?

The first issue in July carried only half a page—this month we print five pages—a tenfold increase. The answer is simply that many firms have found that the right kind of engineers are reading **CONTROL**—the type of man they want to employ. For you this in turn means that **CONTROL** carries notices of some of the best jobs going in the systems and instrumentation business. You will find them on pages 253 and A68 onwards.

CONTROL

NOVEMBER 1958 VOLUME 1 NUMBER 5

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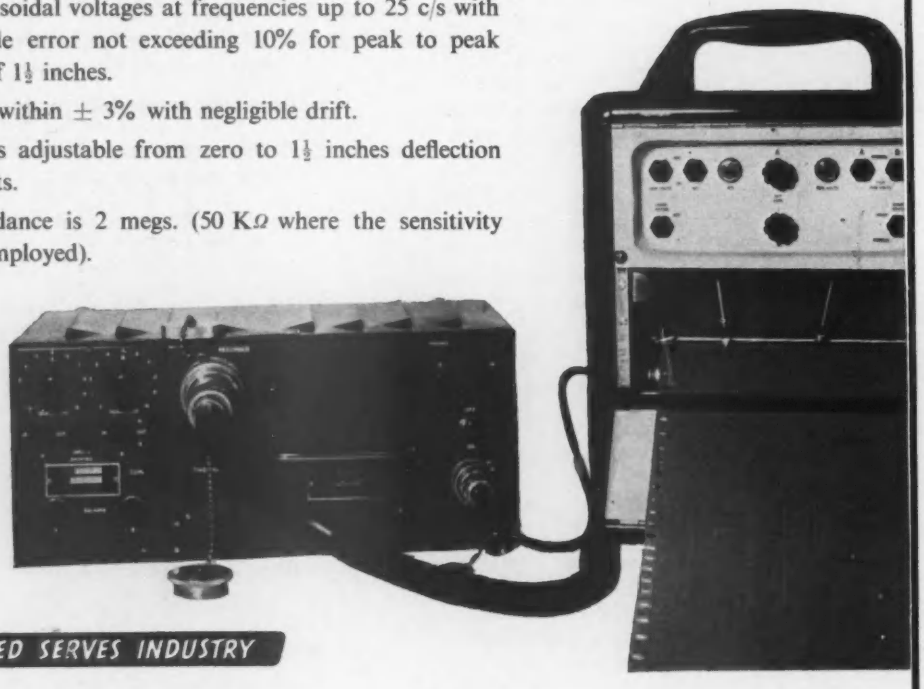

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CONTROL NOVEMBER 1958 VOL 1 NO 5

Tools of Commerce and Industry

WHEN SIR HAROLD GILLETT OPENS THE first British Computer Exhibition this month, his action will signify more than a public-spirited Lord Mayor doing an extra-mural job during a crowded year of office. Both as Head of the City and as an eminent accountant, he will symbolize to many people the growing awareness by businessmen of the computer's importance. Although electronic computers for data-processing have been commercially available in this country for some years, few machines have in fact so far been installed. High capital cost, the difficulty of load factor, uncertainty about reliability, and failure to appreciate the electronic computer's potential uses for them, have restrained many managers of commercial and industrial organizations from embarking on electronic data-processing. But the 'wait-and-see' period is ending. The economic success of the installations that have been made has spread conviction, and computer manufacturers now have the names of more business customers in their order books; interest will undoubtedly be quickened by the forthcoming Exhibition. For many years computers, both digital and analogue, have been accepted scientific and engineering tools. Now in commerce and industry the digital computer, as a data-processer or controller, may be said to have arrived.

Associated with the Exhibition a Business Computer Symposium will be held. Although this will concentrate on the application of data-processing equipment in office and factory, the Exhibition proper will cover all types of computers, both digital and analogue. In this issue we are pleased to present a full guide to and preview of the Exhibition, a survey of commercially available computers, a review of analogue computing for control-system simulation, and articles on computers applied to data-processing and production control.

The last two applications are mixed up with each other and are sometimes grouped under the general heading 'control'. Very little industrial plant and machinery is at present continuously controlled in real time by digital computers. Such control, e.g. in a chemical plant or an engineering production line, is likely to be introduced in the future—with special-purpose computers. But where continual rather than continuous computer control is sufficient, 'break-in' operation of a very fast general-purpose machine may be applicable.

One point can hardly be over-emphasized to those who are thinking about using computers for control. Before a computer can give the most useful results, the office routines or the production control procedure must be fully analysed and made as logical as possible. As Dr Pinkerton points out in an article published this month, computers will not save managers from hard thinking, but much of the thought can take place when the computer is first installed.

Sometimes one hears complaints that there are too many trade exhibitions. But, we believe, room always exists for the specialized show of the type that the Electronic Computer Exhibition will provide. Such an exhibition is well suited for doing business or gaining technical information. This first opportunity of seeing British commercial computers on show together will indeed provide much to stimulate and fascinate anyone concerned with automatic control systems and their applications. We wish the Exhibition every success.

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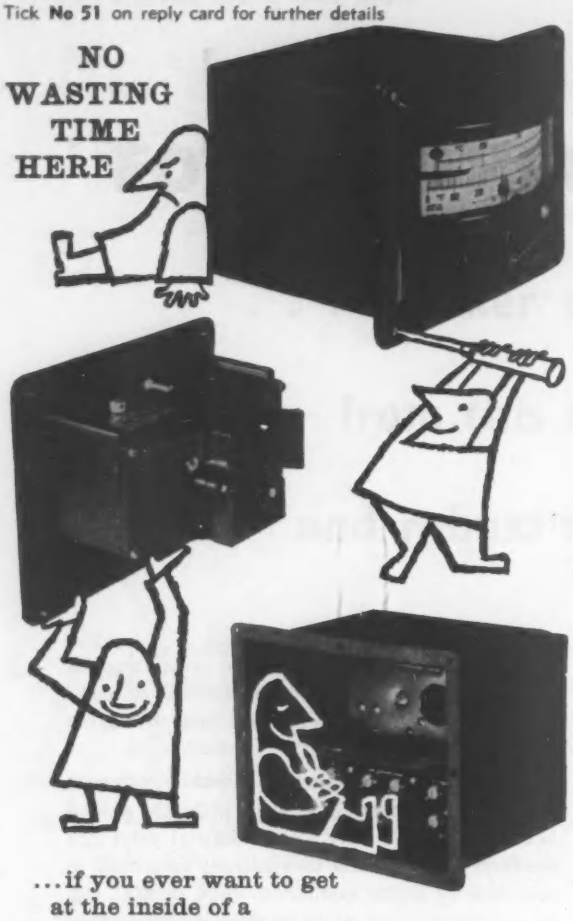

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C/9

SIR! LETTERS TO CONTROL

The Editor welcomes correspondence for publication

A flood of coefficients

SIR: Whilst being delighted at your coverage of hydraulic control valves (CONTROL *Data Sheet*, October p 161), I am rather dismayed at Mr Boyer's addition to the already numerous coefficients which one must remember.

Most hydraulic engineers will agree that there are three basic coefficients relating to orifice flow. They are:

1. C_C. *Contraction coefficient*. The ratio (Area of jet at vena contracta)/(Area of orifice)
2. C_V. *Velocity coefficient*. This is (as Mr Boyer implies) often nearly unity: it is given by the ratio (Actual velocity of jet at vena contracta)/(Theoretical velocity of jet)
3. C_D (sometimes written C_q). *Discharge coefficient*. The ratio (Actual discharge)/(Theoretical discharge).

It follows that $C_D = C_C . C_V$.

I believe from the content of Mr Boyer's Data Sheet that his 'Discharge contraction coefficient' is no more than the normal 'Discharge coefficient' C_D, and would suggest that this term be adopted.

One further minor point concerns the word 'servovalves', which I for one would like to see with a hyphen.

British Hydrodynamics Research Association D. E. TURNBULL

● *Mr Boyer replies as follows:*

'The unfortunate presence of both expressions together resulted from an attempt to compress the text and a probably ambiguous direction to the printer. Dr Turnbull is not unknown to write with tongue in cheek and we may hope that the number of readers similarly bewildered was small. Nevertheless, the writer tenders profuse apologies.

'The definitions in Dr Turnbull's statement, with which those in the Data Sheet fortunately agree, are of long standing, although the symbols used vary from one reference to another. Dr Turnbull's selection is more logical than that adopted by the writer.

''Servovalves', as my good friend Dr Turnbull is doubtless aware, was quite deliberate. Few words retain their hyphens after reaching maturity, or our books (especially his, for hydromechanics as a subject contains longer words than most) would all look like Tiger Tim's Weekly. *The British Hydromechanics Research Association has evidently seen the light. The writer has always felt with electro-hydraulic servo-valves that so dear an object (in several ways) deserved a special, and better, word. After all, any old valve in a hydraulic servo is not necessarily a servovalve. A substantial number of American practitioners share this view'*—EDITOR

Need advertisements be 'waffle'?

SIR: I fork my money over for a technical magazine in the hope of getting hard technical information. Because that is what I want, I do not turn with eagerness and interest to the advertisement pages: I merely 'glance through them'. For, bluntly, 90 pc of advertising matter is what politicians call 'waffle'. I am not impressed by funny little men and faces, vast block capitals, half-tones of the outsides of equipment and yells of self-praise. If the object of that kind of stuff is to get names into my head, it seems a clumsy and expensive way of doing it. Are technicians really so soft-headed as to be taken in by the kind of bawling in print which one expects of and despises in quackery?

But need advertising space be so used? I don't see why. If it has to be paid for, it might as well be filled by matter of real interest and informative value to readers—stuff which would not only be worth paying money to read but which would enhance the technical reputation of advertisers.

Continued on page A47

SIR!

Continued from page A44

I have in mind a very few firms whose advertisements—informative technical text prepared by pukka engineers and not mere copywriters—I cut out and paste into my technical notebooks. I respect and remember those firms, believe they know what they are talking about, believe they have first-rate engineers who can make first-rate products, and am grateful to them for adding to my stock-in-trade of technical knowledge. But the rest . . . ? The only time I look them up is when I want to find an address.

I see no good reason why engineers and scientists on the staffs of firms should not be invited to compile interesting articles to fill advertisement spaces. Surely firms could afford to pay their best men for doing such valuable writing, and allow them the literary privilege of writing as they thought best about subjects that, interesting to themselves, would certainly interest technical readers.

If that were done, I believe one would turn to the advertisement pages with as much interest and confidence that one was going to be told something valuable, as one now does to the text pages of a journal—and would remember the names of sponsoring firms as one now remembers the names of contributors.

London, E17 W. H. CAZALEY

● *In our view, this breezy letter contains more than a grain of truth, though—like many of the advertisement copywriters he censures—Mr Cazaley overstates his case. Technical advertisements are not the right media for articles, but they are ideal for presenting a measure of technical information in an appealing, summarized form—to increase the reader's 'stock-in-trade of technical knowledge', while bringing to his notice a firm's products. Both 'Uncontrolled' in August and the Publisher in his column last month have discussed this subject in* CONTROL. *But we should welcome more views from readers, and advertisers*—EDITOR

Dangerous failing

SIR: I have read with great interest reports of the demonstration of blind landing equipment for aircraft that was recently carried out at Bedford. While fully appreciating the great advance made by the Royal Aircraft Establishment in developing this new equipment, I do feel that there will be some difficulty in winning public confidence in it on commercial airlines. Efficient automatic control equipment is always acceptable provided that it 'fails safe', but this is just what blind landing equipment cannot do. In a demonstration in good visibility the pilot can monitor the performance of the equipment and make a successful manually controlled landing if it fails. But in a thick fog he cannot. The public may accept driverless trains, because trains can be halted automatically if the control equipment fails; aircraft in the air cannot.

Cardiff R. C. MORGAN

● *I think the confidence of the public would be won for any device that could make air services independent of the weather, and so prevent the tiresome delays and diversions which occur at fog-bound airports. In the demonstrations there has been no talk of 'pilotless' planes; the pilot is still very much in command of the aircraft, the landing system being analogous to a helmsman who can see in dirty weather, but who is under captain's orders. At the first sign of a failure the captain can resume control, either touching down by his instruments or attempting a landing at a different airport. Further details of the system will be found in News Round-up this month*—EDITOR

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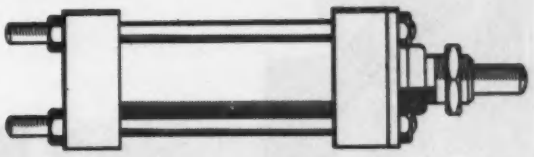

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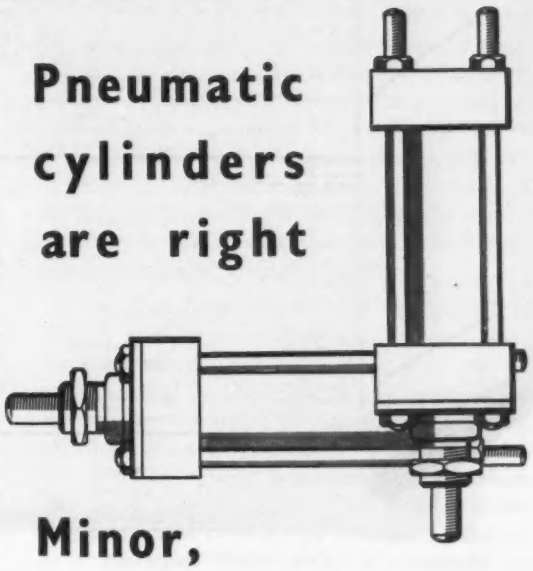

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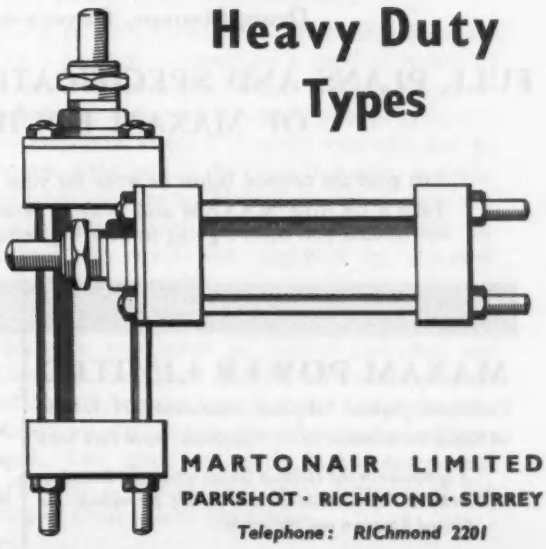

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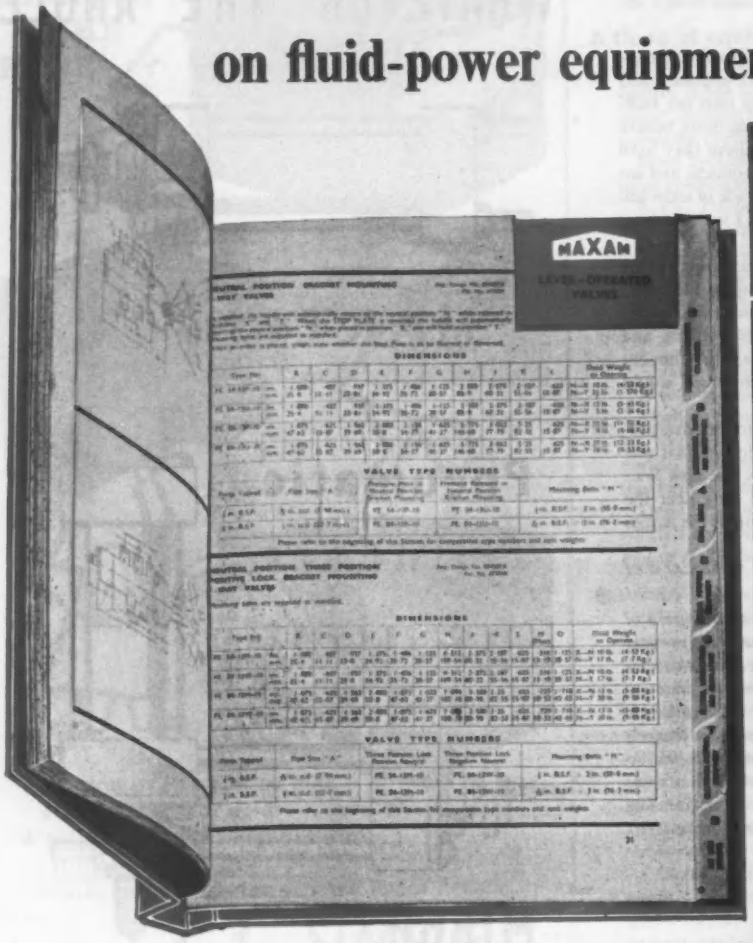

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INDUSTRY'S VIEWPOINT

A monthly article by a prominent man in the control industry on a subject chosen by himself

COMPUTERS—The second decade

by **J. O. TRUNDLE, B.Sc., A.C.G.I., A.M.I.E.E.**
Manager, Control & Electronics Dept, The English Electric Co Ltd

IT IS NEARLY TEN YEARS SINCE THE FIRST LARGE general-purpose electronic digital computers began to take shape in this country. The Electronic Computer Exhibition comes as a timely and significant event, presenting as it will, a synthesis of British achievement in the first decade of computer engineering and an indication of the developments to be expected in the second. Doubtless the Exhibition will make more potential users actively aware of the possibilities of electronic data-processing

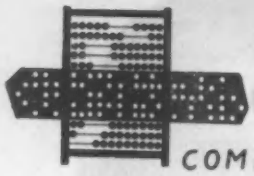
Some of the pitfalls which lie in the path of the unwary have become apparent from past experience. Perhaps one of the most dangerous of these is the failure to appreciate the volume of preparatory work necessary before the installation of a computer. This has been a source of disillusionment to those who have purchased computing equipment and expected great things from it, in both scientific and commercial applications; from this has sprung, quite unjustifiably, an unfavourable attitude in such cases towards the potential of electronic computing. The need for extensive preparation and even radical reorganization cannot be too strongly emphasized if the very great benefits to be derived from electronic data-processing are to be enjoyed to the maximum.

During the early years of computers we have also seen the emergence of a new terminology which must threaten confusion to the uninitiated. It is encouraging therefore to learn of the efforts which are being made to define terms and create a standard glossary which will eliminate certain misconceptions in both management and user. We appreciate the need for standard terminology more readily when we remember the very wide application of computers. The control engineer sees in computing techniques an extension of his logical thinking in control philosophy but the accountant applying electronic data-processing must become accustomed to the phraseology of a medium quite foreign to him. Many executives also will be called upon to make far-reaching decisions concerning the installation and use of computers. The need for a consistent terminology is exemplified by the present lack of a rational basis for assessing the serviceability and reliability of widely differing types of computer. It would be of the greatest value to have a universally accepted standard by which the performance of the various equipments could be judged.

Enthusiasm must be tempered by realism but industry must be prepared to exploit to the utmost the new tools now put in its hands. The next ten years will surely see not only the rapidly expanding use of data-processing in scientific, engineering, administration and commercial applications, but also the use of similar techniques for the real-time control of processing. It is undoubtedly this suggestion of the replacement of the human element by a man-made device which has captured the popular imagination and which has led to highly coloured ideas about the lengths to which automatic control could in the future be carried.

The problem therefore in light-current engineering is twofold: to introduce a sense of reality to counterbalance popular flights of fancy about so-called 'electronic brains' inspired perhaps by reports of long-term forward thinking research; and to convince the man in the street that every material advance achieved in the development of ways and means for greater automatic control will be exhaustively tried and exploited in whatever practical way possible.

One thing is clear: the greater our reliance on electronic equipment to control processes and functions, the larger the number of components which will be used, and thus the higher the reliability we shall require of each individual component. The speed at which higher component reliability is secured will be a measure of our rate of advance into automation.



COMPUTER SECTION

DIGITAL COMPUTERS IN CONTROL

by **MAURICE V. WILKES, F.R.S.**

Director of the Mathematical Laboratory, Cambridge University
President of the British Computer Society

LESS THAN TEN YEARS AGO THE NUMBER OF DIGITAL computers in operation was very small, and only a few specially favoured workers had access to them. Now they are regularly found in universities and scientific research organizations, and are beginning to appear in engineering design departments and in offices. There can be no doubt that digital computers will have their part to play in automatic control, although this is a field in which much pioneering work remains to be done.

Science → Business → Control

It is perhaps not very surprising that scientific research was the first field to be invaded by digital computers. The early machines were more suited to scientific work than to other classes of work, and the scientific research worker could make use of a machine if it were available without upsetting the organization of an office or a factory. Engineering designers, with a few notable exceptions, have perhaps been relatively slow in taking advantage of digital computers, but there are signs that this situation is now being rectified.

Many business applications of digital computers are, in a sense, control applications, since the object is to provide management with information which will enable a commercial undertaking to be run with greater efficiency. However, this is not *automatic* control, since human beings are involved in the control loop in a non-trivial manner.

Digital computers and analogue computers are often mentioned together, as though there were a straight competition between them like the competition between gas and electricity for domestic heating. I do not think that this is a true picture, certainly not in the control field. Analogue computers are ideal for use in a controller performing some local and rather simple job. If digital computers come into their own in this field, it will be for use in situations where decisions of a relatively complex character have to be taken, and where relatively large quantities of data have to be collected, stored and analysed. I should perhaps make it clear that I am here concerned with computers actually used in control systems. Computers are also required for use as simulators to aid in the *design* of control systems, and this domain analogue computers have, so far at any rate, made peculiarly their own.

Load factor is a difficulty

One difficulty in the way of the utilization of general-purpose digital computers in the control field is that many applications, while employing all the facilities of a general-purpose digital computer, would not keep it busy for more than a small fraction of the time. The automatic control of a machine tool is a case in point. In these circumstances it is natural that people should have developed special-purpose computers. These computers certainly contain very much less equipment than is to be found in a general-purpose digital computer; however, the amount of equipment is seen to be quite large for what the computers do, if this is reckoned up in terms of computation performed and decisions taken.

Time sharing

One way out would be to have, in a factory or workshop, a central digital computer controlling a large number of machines on a time-sharing basis. The development of time sharing or 'break-in operation' has been one of the major recent developments in digital computer technology and is likely to have repercussions on all fields of application of these machines; in control engineering it may well prove decisive. One digital computer —with perhaps another as a standby—could control a great many machines in a workshop, and could perhaps also assist with the co-ordination of their activities at a higher organization level. It might, for example, supervise, and even regulate, the flow of work or the allocation of tasks; at all events, it could act as a watchdog and direct the foreman's attention to bottlenecks before they become serious.

The principle of time sharing has long been known to automatic telephone engineers. Its application to a digital computer used for control would be as follows. The digital computer would have connected to it a number of peripheral devices, each via its own group of wires. Some of the devices might be conventional input and output devices such as card-readers or printers; others would be production-line machines for which the computer would provide a control service. Normally, the computer would be operating on some task which would provide a base load; this could consist of technical or business calculations, not necessarily connected with the control functions being exercised by the machine. Whenever one of the peripheral devices was ready to transmit information to the machine for storage, or ready to receive information (perhaps the result of a decision) from the machine, it would seize control of the machine for the brief interval of time necessary. Normally, this time would be measured in microseconds rather than in milliseconds. Each device would be accorded a degree of priority, highest priority going to the device which operated at the highest speed.

The above proposal implies a measure of centralization. This is not necessarily a disadvantage if computers can be made reliable enough, and perhaps very much depends on what transistors are going to do for us in this respect. In other fields centralization has brought great advantages. A good example is in the generation of electricity; it may seem rather far fetched to compare this with the use of computers in control, but the principles are just the same. Concentration of power generation in a relatively small number of generating stations has enabled economies to be made in maintenance and in operation, and has allowed advantage to be taken of the higher technical efficiency of large-scale modern plants. Similar advantages accrue with computers. In fact, the advantage of using one fast, large computer instead of a number of smaller and slower devices might well be very striking. One sees this by comparing digital computers themselves. The larger machines now on the market are fifty or a hundred times faster than the slower ones, but do not cost anything like fifty or a hundred times as much.

Reducing maintenance

Anything that will reduce the amount of maintenance effort required is a step in the right direction. The maintenance of a large number of special-purpose computers would call for an army of technicians. It is becoming clear that if the number of digital computers and special-purpose devices of similar complexity continues to increase at the present rate, it will just not be possible to find enough technicians of sufficiently high calibre to keep them going. The shortage of technical manpower, if nothing else, is an argument for having, where possible, a few very fast general-purpose machines, efficiently loaded, rather than a multiplicity of special-purpose devices amounting, in the aggregate, to a much greater quantity of hardware.

BUSINESS COMPUTER SYMPOSIUM

Held at Olympia in conjunction with the Electronic Computer Exhibition

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2.15 p.m. to 4.30 p.m.

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Computer Services in the United Kingdom	D. WRAGGE MORLEY *Financial Times*

SESSION 2. *MONDAY, 1st DEC*
6.0 p.m. to 8.15 p.m.

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Chairman, Scientific Advisory Committee, Trades Union Congress

Large Scale File Maintenance	D. G. PEDDER *Radio Rentals Ltd*
Technical Planning of Steel Tube Manufacture	R. G. HITCHCOCK *Tube Investments Ltd*
Public Utility Accounting	G. SHERLOCK *South Western Gas Board*
Electronic Data-Processing in the Nationalized Industries	DUDLEY W. HOOPER *National Coal Board*

SESSION 3. *TUESDAY, 2nd DEC*
10.15 a.m. to 12.30 p.m.

CHAIRMAN: SIR WALTER PUCKEY
The British Institute of Management

Inventory Control, Accounting and Payroll	A. BRADLEY *Ford Motor Co Ltd*
Production Control by Buying Computer Time	R. B. BAGGETT *Job White & Sons Ltd* G. M. DAVIS *English Electric Co Ltd*
Accounting for Farmers' Sugar Beet Production	J. P. LAWLER *Irish Sugar Co Ltd*
Electronics in Banking	L. TEMPLE *Clearing Bankers Electronics Sub-Committee*

SESSION 4. *TUESDAY, 2nd DEC*
2.15 p.m. to 4.30 p.m.

CHAIRMAN: SIR JOHN SIMPSON
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Practical Application of a Small Commercial User	D. L. ROWLANDS *A. C. Neilson & Co Ltd*

SESSION 5. *WEDNESDAY, 3rd DEC*
10.15 a.m. to 12.30 p.m.

CHAIRMAN:
LORD DE L'ISLE AND DUDLEY
President, Office Management Association

The Application of Linear Programming to the Design of Animal Feeding Stuffs	A. MUIR *J. Bibby & Sons Ltd*
Integrating the Procedures of an Insurance Office	K.-E. SCHANG *AB Datacentralen (Sweden)*
The Approach to EDP of a Large User	S. G. FURNISS *Imperial Chemical Industries Ltd*
A Practical Application in Commerce	J. F. BODY *Newton Chambers Ltd*

SESSION 6. *WEDNESDAY, 3rd DEC*
2.15 p.m. to 4.30 p.m.

CHAIRMAN: MR H. J. FURNESS
President, Institute of Cost and Works Accountants

Analysis of Sales Statistics	C. A. WILKES *Imperial Chemical Industries Ltd*
Wages Accounting	W. H. SARGENT *British Railways*
Industrial Mathematics	D. G. OWEN *United Steel Companies Ltd*
Electronic Data-Processing	A. J. BROCKBANK *Glaxo Laboratories Ltd*

COMPUTER SECTION

COMPUTERS ON SHOW

Olympia, 28th Nov—4th Dec

Computing and data processing techniques are establishing themselves with astonishing speed in laboratories, factories and offices all over the country. London's Electronic Computer Exhibition, previewed here, gives a comprehensive display of the latest types

Air Trainers Link (14)

The main exhibit, which will be shown in operation, is a small mechanical computer; the company makes a range of mechanical and electrical units which can be interconnected by a system of stainless steel tapes and assembled to form analogue computers.

Benson-Lehner (GB) (12)

The company's Oscars enable data recorded on strip charts to be calibrated and punched into cards or tape at rates up to 1000 data points an hour; while other apparatus displayed can read information from punched cards or tape, or from cine film and show it visibly in the form of a moving graph, as well as feeding it into data processing equipment.

British Olivetti (42)

A tape-to-card converter operating at 600 digits a second will be on show. Using transistors and germanium diodes and including a magnetic core memory, it is claimed to be exceptionally flexible in data combination.

British Tabulating Machine Co (5/7)

As well as demonstrating their Hec electronic computers, BTM make a feature of the practical application of computers to industry and commerce. The whole picture of electronic data processing is presented and the computer, as a business tool, is put into perspective. Major working exhibit is the 1201 general-purpose digital computer, which can take Hollerith 80 column punched cards at a speed of up to 5100 an hour. Another is the 555 'plugged programme' computer. The company says: 'Electronic machines operate with more efficiency and greater economy when their menu is logically presented—an aid to digestion!—and the automatic sorting and collating of basic data, for machine processing by sorters and collators, will be shown in action.'

British Thomson-Houston Co (8)

An exhibit aims at showing that a combination of digital/analogue converter and Helisyn control can position a tool table with an accuracy of one ten-thou of an inch from a decimal numerical input. Still under development, the Helisyn consists basically of a short cylindrical part which can be moved along—but is not in contact with—a longer cylindrical part, each being provided with conductive paths in the form of interlaced helices. One of the elements is excited electrically by suitable voltages set up in accordance with the input number, and a misalignment signal is electrostatically induced in the other element.

Bulmer's (Calculators) (45)

Equipment for automatic data processing in connexion with automatic weighing procedures will be demonstrated. The routine involves automatic registration and processing of fixed supplier data complemented by variable data from the scales, which are then processed by punched cards to obtain the final results.

Burroughs (28)

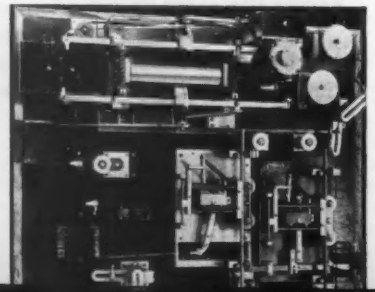
The E101 and scale models of the 205 and 220 electronic digital computers will be on view. Designed to fill the gap between standard desk calculators and large scale machines the E101 is about the size of an office desk, costs £16 500. About 170 are now in use. Usual input is by keyboard—though punched tape or cards can be used—and most interesting feature is the pinboard programming unit which involves storage of instructions separately from data; magnetic drum storage capacity has been increased to 220 words. For the big machines, 205 and 220, magnetic drum and magnetic tape storage systems are available up to a capacity of 48 million words, with input by paper tape or punched cards. Also on show are new types of keyboard machines for book-keeping accounting which depend to some extent on magnetically recorded information incorporated in the documents themselves, and an electromagnetic read-write head on the machine.

Creed & Co (30)

Among a really comprehensive display of punched tape equipment and tele-

205 computer—*Burroughs*

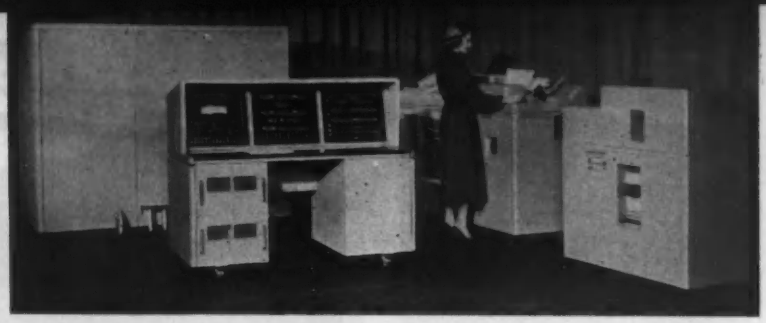
Mechanical analogue computer—*Air Trainers Link*



printers the company will unveil a new tape punch which will feed out results at 3000 words a minute! Punched tape outputs have always been a bottleneck and most computers at present are fitted with equipment which can punch out about 300 words a minute—very much slower than the computer could produce them—so that the new punch should arouse considerable interest. It is driven by an induction motor and operates on a multi-wire start-stop basis, incorporating revertive signalling arrangements for input control. Each of the individual punch pins is selectively controlled by an electromagnet and the punching force is supplied by the motor-driven cam shaft. Tape feed is selectively governed by a pair of electromagnets, which actuate to control a pair of camshaft driven feeding frames, each feeding frame being alternately timed to advance the tape in a step-by-step manner. An experimental serial output printer on show also marks a considerable advance on previous speeds.

Elliott Brothers (London) Ltd (35/43)

A new general-purpose electronic digital computer, the 802, appears for the first time. Relatively low-priced, it makes extensive use of transistors, printed circuit techniques and plug-in construction, and the three units—store and arithmetic, console and input/output, and power, are all only 2 ft 8 in. high. Power consumption is very small at 2kVA so that running costs should be moderate, with less worry than usual about waste of computer time. No air conditioning is required and weight is low enough to eliminate special care in siting. It contains only one magnetic core store, capacity 1020 words of 33 binary digits each, and speeds are: addition and subtraction 0·612 millisec, multiplication and division 21·4 millisec. Operation is controlled by three keys only, and a loudspeaker indicates when the machine is calculating and produces a sequence of tones according to the instructions being obeyed.



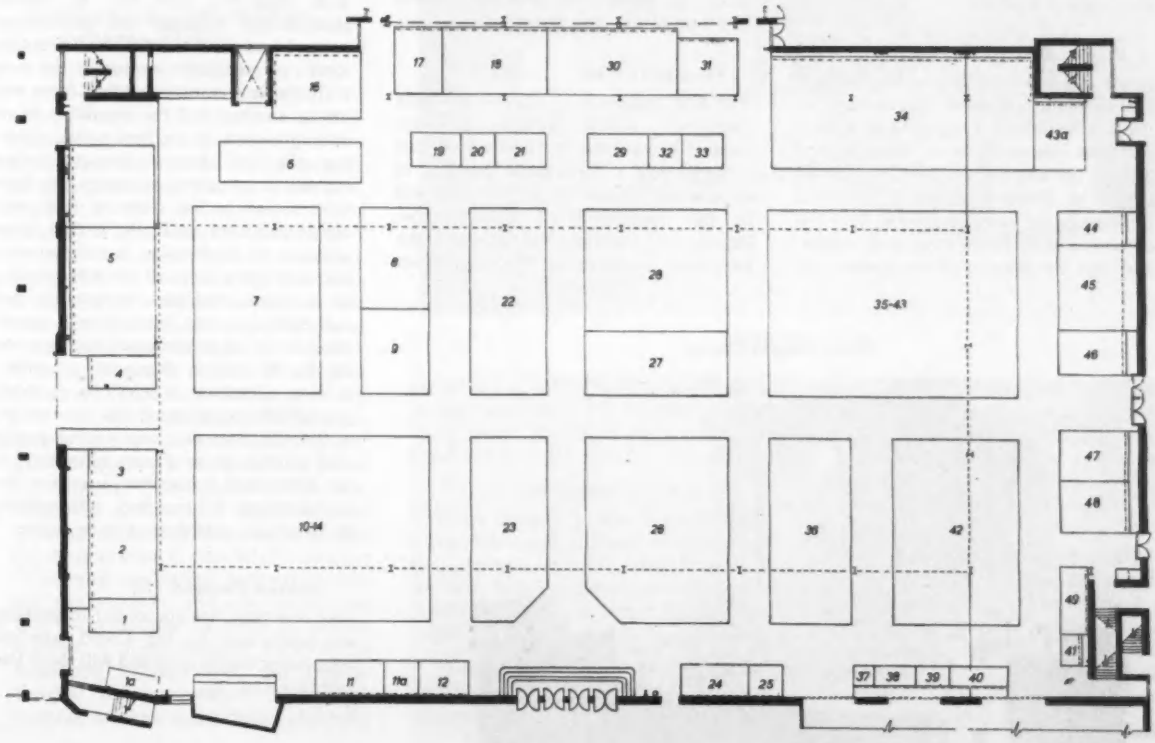
Hollerith 1201—B.T.M.

DON'T MISS

- ★ **Tape-to-card converter**—*British Olivetti*
- ★ **E101 desk size computer**—*Burroughs*
- ★ **Helisyn control**—*British Thomson-Houston*
- ★ **3000 w.p.m. tape punch**—*Creed & Co*

EMI Electronics (26)

Emphasis is on transistorized computers. An Emidec 1100 electronic digital machine will be on show, and the new 2400, not yet completed and much too large to show in any case, will be illustrated and explained. With its associated input/output equipment and high speed magnetic tape units, the 1100 is designed as a flexible data-processing system for anything from medium sized business concerns to the most complex of commercial problems. Unit construction is employed so that each section can be independently made and plugged in to form a complete machine. Magnetic cores and transistors mounted on printed circuits are used throughout. The 2400 is constructed on similar lines and will form a very large high speed system—it could, for example, be applied to a mail order company with some two million accounts, to handle all the invoicing, stock control, accounting, and production of standard 'pay-up' letters. Backing up the main



3000 tape punch—*Creed & Co*

802 computer—*Elliott Bros*

Magnetic storage drum—*E.M.I.*

exhibits will be a new 8000 word digital magnetic storage drum with 128 information tracks.

English Electric Co (36)

Main display is of course on the well-known Deuce—Digital Electronic Universal Computing Engine—and experts will give demonstrations using a land link to the company's main computing centre at Stafford. Mark I, intended principally for scientific work, uses 64-column punched card input and output, and can be fitted with magnetic tape auxiliary storage if required. The input and output system for Mark II is combined in a single unit using all 80 columns of the standard punched card equipment, and normally the computer would be equipped with magnetic tape auxiliary storage. It has been designed primarily for data processing and a dioramic display will show a typical lay-out. An interesting item of peripheral equipment on view for the first time will be a new card operated typewriter, also in operation in conjunction with the land link.

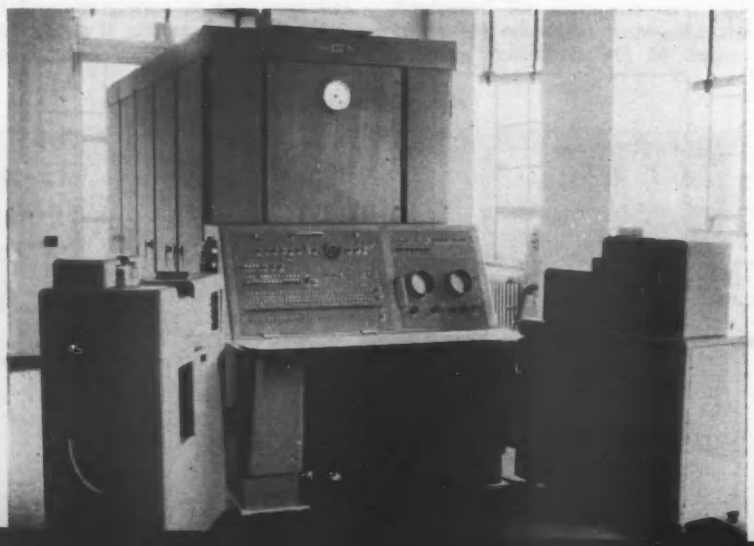
Fairey Aviation Co (32)

Highlight is a multi-purpose electronic analogue computer. Printed circuit and plug-in techniques are used to make it as flexible as possible and a computer of any desired size can be built up. Basis is a computing panel housing 12 d.c. amplifiers.

Ferranti (10/14)

The first company in Europe to make electronic digital computers commercially available, Ferranti's have now accumulated a formidable amount of experience. Illustrated at the show will be the medium sized multi-purpose Pegasus—a working exhibit—and the two large computers: Mercury, tailor made for the nuclear industry, and Perseus, designed for commercial applications. All three make extensive use of printed circuits and plug-in construction. Mercury's application to scientific work is helped by its great speed, and a simplified programming method which in conjunction with a floating point system slows down the computer by a factor of only 2 to 1. The latest and biggest of the Ferranti computers is the Perseus data-processing system, which markets at something like £300 000. This is its first public showing, and a model will carry out the basic office procedure of up-dating a file of information.

Deuce—*English Electric*



IBM United Kingdom (34)

Four main types of equipment will be on view. The IBM 650 computer system with magnetic tape will be shown alternatively engaged on production control and mathematical and scientific work; of particular interest is the ease with which it can be switched from one job to another and the simplicity of its coding system. In its first public showing, the 305 Ramac data-processing system, a complete, compact machine built round a disk memory unit, will demonstrate its ability to handle large amounts of information in a simple way and will show how all records relating to a single business transaction are automatically and immediately amended; it can be interrogated for any one of the 10 million characters of information contained in its store. A stock availability programme will be run on a 604/421 electronic accounting group and another piece of new equipment is the IBM data transceiver, used for the transmission of punched information by telegraph, telephone line or radio.

Lamson Paragon (31)

The company has succeeded in gearing its form feed to the Creed tape-fed teleprinter output unit and will show the combined set up.

Leo Computers (27)

This stand is arranged as an information centre about the Leo 'automatic office': what it consists of, what it can do, and what services the organization offers to science and industry. The home of the Leo computer is only a hundred yards away from Olympia, and visitors can fix up to go and see Leo I or Leo II—the production version—at work earning its keep on routine clerical and data processing work. A control desk and test rack will be shown on the stand with illustrations of the central computer and the printers, magnetic tape units, magnetic drums and paper tape and punched card input/output equipment that can be coupled to it.

Logabax (46)

An accounting machine linked up to a punched tape interpreting apparatus will be shown. It is controlled by means of a standard 5-channel perforated tape instead of by an operator using a keyboard and produces a printed record of all input and output figures. Input and output can be handled at the rate of approximately 2400 items (words of up to 20 digits) per hour.

DON'T MISS

- ★ **Analogue computer**—*Fairey Aviation*
- ★ **Leo**—*Leo Computers*
- ★ **1010 transistorized computer**—*Metrovick*
- ★ **609 process information system**—*Panellit*

Metropolitan-Vickers Electrical Co (22)

Main item will be a scale model of the 1010, a new fast transistorized computer for data-processing and real time process control. A novel feature is the data scanner, which transfers information between the store and all ancillary equipment. It interlaces the transfers automatically word by word, with the execution of computer instructions, and it can maintain simultaneous transfers of blocks of data to or from all ancillary apparatus. This system enables relatively slow peripheral equipment to be connected 'on-line' to a very fast computer, without delaying computation by printing out, etc. Other points are parallel arithmetic circuits and magnetic core working store. Facilities are provided for the operation in parallel of a number of programmes having compatible storage requirements, and any programme may be interrupted in order to execute another of high priority. Two of the remaining exhibits are also transistorized: the inexpensive 950 general-purpose medium speed digital computer intended for universities and small firms, and the 960 paper tape reader, a compact self-contained unit designed to read 5-channel tape at up to 250 characters a second.

Mullard (2)

Semiconductors and valves designed specifically for computer work are on view; the new high frequency power transistors, types OC23 and OC24, capable of providing 700 mA pulses of a duration, for example, of 2 microsec, with rise times of less than 0·5 microsec; also gold-bonded germanium diodes for use with transistors in high-speed computing circuits. The Mullard ferrite store system, driven by these new semiconductors, will be shown.

Perseus—*Ferranti*

Ramac 305—*I.B.M.*

Mullard Equipment (11)

Exhibits include a new high-precision measuring system for use with machine tool control systems, and a new 1 millisec variable magnetostrictive wire delay line for use in computers at pulse repetition frequencies of up to 1 Mc/s.

National Cash Register Co (35/43)

The company's main exhibit will be a complete National-Elliott 405 electronic data-processing installation and ancillary equipment. Automatic compiling and line assembly equipment incorporated in the system centre facilitates conversion during input from decimal or sterling to binary scale and assembly of telecode characters into the computer wordbase, and carries out the reverse processes during output. This equipment includes a new automatic 5/6, 6/5 bit conversion device. It was designed as the centre of an integrated data processing system and operates from one original recording of the basic data. As a by-product of routine applications, and without disturbing them, it can produce at any required intervals items like exception reports, summaries, comparisons, and sales and production forecasts.

Panellit (49)

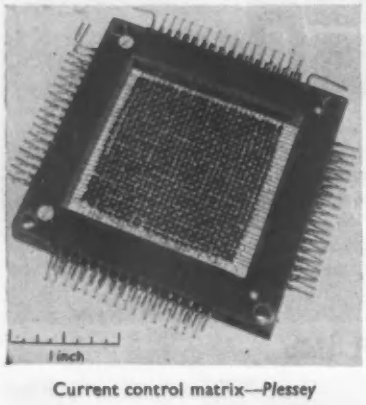
One of the Elliott-Automation group, Panellit will show the new 609 process information system. This comprises an automatic scanner for examining any rapid succession up to 200 process measurement points, data-storage and reduction units to give off-normal indications and alarms when values deviate

beyond preset limits, a computing unit for continuous calculations of overall process efficiency or other desired information, and an automatic high-speed electric typewriter for printing out results in tabular form.

Percy Boyden & Co (1)

A new range of computer tapes will be on show. Special tapes are available for computers, data-processing and process control in 5, 6, 7 and 8 channels in a variety of colours.

National-Elliott 405—*National Cash Register*



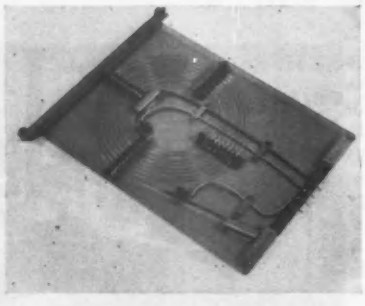
Current control matrix—*Plessey*

Plessey Co (6)

A variety of memory cores and some complete memory stores will be displayed. Square loop ferrite types for use in high speed random access memories range in size from 0·5 to 0·375 in. o.d. Two special machines have been developed for testing: one of them individually inspects each core and the other carries out automatic testing procedure on complete memory planes. Transfluxor type cores include units with multiple apertures, which can be used in magnetic devices to replace valve flip-flop circuits or in non-destructive readout memories.

Powers-Samas Accounting Machines (10/14)

The company gives a first showing of Pluto—a new large scale electronic computer system which has been developed in collaboration with Ferranti. It is intended for either scientific or commercial use, and punched cards, perforated tape and magnetic tape can



Wire delay line—*Mullard Equipment*

be used as input or output media at will, giving speeds of 480, 300, and 9225 characters a second respectively. Some use is made of transistors and printed circuits and speeds are high—addition for example takes $\frac{1}{4}$ millisecond and multiplication 2 milliseconds. Inbuilt storage capacity is over 8000 words, and comprises magnetic drum and nickel delay lines. A good speed of printed output is achieved by a new version of the Samastronic output printer. It functions with magnetic tape carrying the results from the calculating unit: tapes are produced at 9225 characters per second and the Samastronic can print 30 lines of 140 characters a minute. Other exhibits include the PCC medium scale computer.

Punched Card Accessories (29)

Various ways in which information sources can be filed so that they are quickly available will be shown, and simple and rapid means of transporting the necessary batches of cards or reels of tape from the library to the computer.

Rank Xerox Industries (48)

First public showing of a computer output printer which uses the xerography technique instead of the conventional type-and-ink equipment. Still in the experimental stage it can already print out at the phenomenal rate of 1500 lines a minute, and the company plans to reach 3000 lines a minute. At Olympia pre-printed forms will be used but the next step is an arrangement to enable the device to print its own forms as it prints the computer output, giving greater flexibility to the system and cutting down running costs considerably: layout of the final printed form can be predetermined by coded instructions fed to the computer. Well established in America but only recently introduced to this country, the xerography technique is one of the most interesting developments in modern reproduction: it is completely dry and automatic, works by electrostatics. Originals either on paper or a cathode ray screen can be copied onto plain unsensitized paper at the rate of 20 ft a minute. The unit on display will have a repertoire of 50 characters, printing up to 128 across paper 13 in. wide. It works either from magnetic tape or straight from the computer's buffer store.

Saunders-Roe (19)

The company has recently adapted a system of using plug-in units to build up a complete analogue computer and an amplifier mounting panel with five amplifiers will be on view; they allow an integrated piece of equipment to be set up with the front of the panel forming the patch panel. All the necessary control relays for the amplifiers are contained in the unit so that the panel and its amplifiers need only a power supply—300 volt silicon diode units are used—to become a complete computer. A computer built in this form and consisting of 20 counting amplifiers, 40 coefficient potentiometers, a servo-multiplier and a force function generator, with a two channel servo-operated quick response pen as recorder, will be seen at work.

Semiconductors (6)

High-frequency transistors designed for digital computer use. Of particular significance among these are the SB 240, which has low and controlled saturation resistance, controlled input characteristic and specified high-frequency beta and hole storage factor, and the 2N 501, a micro-alloy diffused base transistor with rise, fall and storage times in the order of 10 millimicroseconds.

Short Brothers and Harland (4)

The exhibits draw attention to the amplifier units designed to meet the needs of users requiring only a small number of computing units to fit into an existing system. A short general-purpose analogue computer will be on view. An interesting feature is continuous drift correction, which enables computing times to be extended up to an hour or more; the linear function unit consists of a high-gain computing amplifier, together with an auxiliary amplifier which provides continuous correction of any drift in the computing amplifier.

Siemens Edison Swan (16)

On this stand is a new miniature uniselector which has been specially designed as a plug-in unit for mounting in the space of a Post Office 3000 type relay. Of particular interest to builders of electrical automatic machines, it is said to operate for two million revolutions without need for readjustment, and weighs only 12 ounces complete. Functioning high-speed motor uniselector equipment and similar selecting devices are also being demonstrated. A working exhibit of transistor operated magnetostrictive delay lines and high-speed transistor logic circuits can be seen, using transistor types XA 102 operating at 500 kc/s. The equipment has been programmed to work as a 'fruit machine' which can be operated simultaneously by two players.

Solartron Electronic Group (9/18)

The Solartron Electronic Reading Automaton—ERA—will be shown as a production model for the first time. This can scan a page of typewritten figures and convert them into electrical impulses so that written figures can be fed directly into data-processing machines or computers. The model shown is bound for Boots Cash Chemists Ltd, Nottingham, where it will read the cash register rolls from all their stores (*News Round-up* October). Saki (Solartron Automatic Keyboard Instructor), also on view, is the first of a family of electronic teaching machines; it enables punched-card operators to be trained very much more quickly than by conventional methods. It can also size-up the potentialities of a trainee very early in the instruction course. Other exhibits include the Minispace, a popular analogue computer small enough to be used at the side of a designer's desk.

DON'T MISS

- ★ **Computer transistors**—*Semiconductors*
- ★ **Electronic Reading Automaton**—*Solartron*
- ★ **Stantec-Zebra computer**—*Standard Telephones*
- ★ **Tape Merger**—*Ultra Electric*

Southern Instruments (24)

Data reduction equipment includes the K1028 with programme unit, which offers separate calibration of each channel, and the K1020 trace reading equipment which will accept up to 6 in. records and incorporates preset calibration for non-linear records. Other features of the company's equipment are digital output in actual physical units shown on visual display for quick reference, and permanent records by typewriter, tape or card punch.

Sperry Gyroscope Co (39)

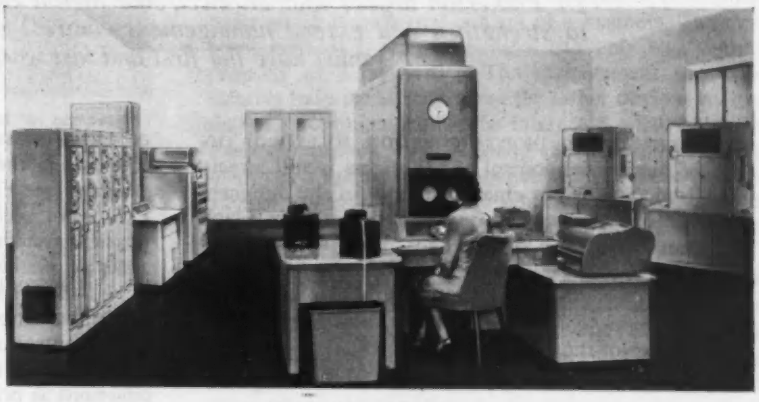
A magnetic storage drum which Sperry developed in collaboration with the Automatic Telephone and Electric Company Ltd—originally for use in automatic telephone switching systems—will be on show. It is capable of application to a much wider range of computer systems, particularly where high-density storage of information is called for. Design is based on marine gyro-compass techniques, where an operating life of 20 years is commonplace, and it is reported that its surface finish (better than 16 micro inches) and extreme accuracy of bearings combine to make it almost impossible to see whether it is rotating or not.

Standard Telephones & Cables (23)

Main exhibit is the Stantec-Zebra, one of the lower cost general-purpose electronic digital computers made in the UK. It is partly transistorized with a power consumption of only 3 kVA. The storage capacity is 8192 words and output is normally punched paper tape. Programming method is flexible: fairly simple codes can be read so that comparatively unskilled operators can programme specific problems after very little instruction. Numbers can be in fixed or floating point form and the basic fast sub-routines used without modification.

Ultra Electric (10/14)

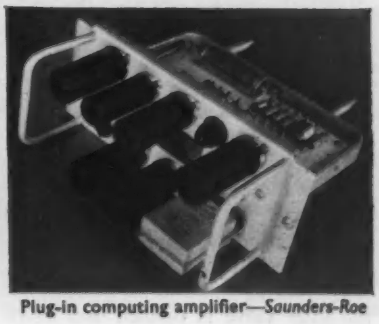
The company's tape merging equipment will be shown for the first time. This new all-transistor apparatus may be used in the tape editing room to merge the information on two punched tapes, so producing a combined tape. The specification was prepared by Ferranti Ltd.



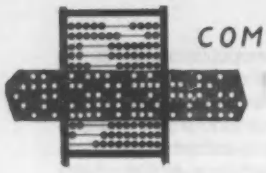
Pluto—*Powers Samas*

Output printer—*Rank Xerox*

Miniature uniselector—*Siemens Edison Swan*



Plug-in computing amplifier—*Saunders-Roe*



COMPUTER SECTION

CONTROL BY NUMBERS

1 What part can the computer play in business control?

by **J. M. M. PINKERTON, M.A., PH.D.**
Development Manager, Leo Computers Ltd

Dr Pinkerton argues that an electronic digital computer can be used to strengthen and extend management control, but that management must have the first and last word

THE ABILITY OF THE DIGITAL COMPUTER TO EXTEND THE span of managerial control of a business is still largely unrealized. This is not chiefly the fault of the designers and operators of computers; it arises rather from a lack of human imagination, and perhaps also of the necessary intellectual outlook in many managements, who might be making good use of computers. I hope that this article will be helpful to some of them in showing them the potentialities of the computer.

The computer as a control system component

In this article I shall regard the computer installed in a business as part of a complete control system, the rest of which is formed by the people engaged in it. Though this is, of course, not the only way or necessarily the best way to consider the relationship between a computer and the business it is intended to serve, it may be a worthwhile exercise.

Let us consider what is involved in any automatic control system. Take as a familiar example a domestic cistern in which water is automatically maintained at a nearly constant level. If water is drawn off, the level falls and the ball valve opens the inlet so that more flows in from the main. The greater the outflow the greater the drop in level, and therefore the wider will the inlet valve open. Thus there will be a rough proportionality between the size of the drop in level, i.e. the error, and the rate of inflow of water to correct it. All the classical features of an automatic control system are present. There is first of all an error condition, a deviation from the set standard —the water level has fallen. Then there is an error detection means—in the form of the floating ball on the end of an arm. Next there is feedback to the error correction means by the mechanical connexion of the ball arm to the water inlet valve. This feedback is negative in the sense that as water flows out and the level tends to fall, the inlet valve is opened and more water flows in to correct the level again. The relationship between these elements in the control system may be illustrated in a diagram (see Fig. 1).

It is not necessary to restrict the concept to a purely physical system. Control systems can be discussed (and analysed mathematically) some of whose elements exist only in the abstract; for example economists measure and predict variations in supply and demand. The quantity under control may be the amount of goods produced in a factory, but the feedback path may involve such abstractions as price, delivery dates, wage rates, and so on. Nor need the standard condition towards which the system is intended to regulate itself be fixed and unvarying. It is quite permissible that the standard should vary, but most important that it should not change too much within the time of response of the system. If the standard is changed too rapidly a system may either fail to follow the changes at all or be set into violent oscillations.

. . . worth emphasizing

It is worth emphasizing the absolutely fundamental position occupied by the error in all control systems. Without feeding back the error signal there can be no automatic correction. Control systems therefore in which no error signal is fed back at all are less satisfactory and less likely to follow exactly any variations in the standard. They correspond to the behaviour of a weak management which gives the correct instructions but takes no steps to check that its employees carry out those instructions to the full. On the other hand by magnifying the error signal sufficiently the remaining error after correction can be made as small as one pleases. Too great a delay in the feedback of the error signal may also provoke oscillations.

When the computer is incorporated in a control system it makes for much greater sensitivity since more figures can be checked more accurately for small deviations from previous trends. It can also diminish the time of response

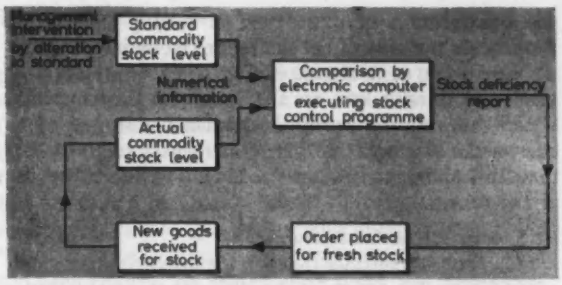

Management intervention by alteration to standard
Standard commodity stock level
Numerical information
Comparison by electronic computer executing stock control programme
Stock deficiency report
Actual commodity stock level
New goods received for stock
Order placed for fresh stock

Fig. 1 Generalized representation of an automatic control system. Notice that the human intervention with the state to which the system adjusts itself is by an alteration to the standard condition

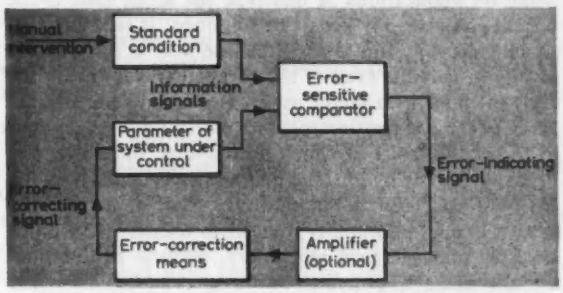


Fig. 2 Highly simplified representation of a computer integrated with a stock control system. The diagram has been drawn to bring out the parallels with Fig. 1

since the error indications can be computed faster and the system is potentially able to return to the standard state more quickly. It will tend therefore not to depart so far from it. Considerations such as these justify the introduction of computers for control purposes of all kinds.

Computers in control

The British Civil Service divides its senior officers into the executive and administrative classes. Executive officers are supposed to carry out the policies of the officers in the administrative grades. Somewhat corresponding to these executive and administrative functions there are broadly two ways in which computers can exercise control in industry and commerce. The first way is to connect a computer to the productive machinery of a factory so as to displace some or all its operatives, and let the computer actually regulate production more or less directly. Examples often quoted of factories that might be run in this way are continuous process plants of various kinds such as oil refineries and chemical works. Actually no computer has yet been fully put to use in this way, perhaps for two reasons:

1. No sufficiently reliable computer has yet been built.
2. The rules governing the regulation of a complete plant are so complex that no one has yet succeeded in formulating them. Unless this is done no computer programme can be written to carry them out.

Probably the first of these two reasons is ultimately the more important. Though small process control computers are made, e.g. by the Ramo-Wooldridge Corporation of California (*1*), it is doubtful whether they have yet been successfully used to control more than a single process. Control of machine tools by direct link with a general-purpose computer is also possible but would probably be very uneconomic. Fortunately a direct link is not necessary—a set of control instructions punched in paper tape can be prepared once and for all for a given part, and used to control the machine tool. This is far more economical especially as the production of the control tape by the computer would take only a small part of the time taken by the tool to machine the work-piece once. Several successful applications of this kind have been reported (*2*).

Apart from indirect control of this kind we may therefore say that in the near future the control exercised by a computer on the factory is generally going to be much more indirect—the control it will exercise will be administrative. It will produce documents for invoicing goods, paying wages, controlling stocks and so on, and human beings will often be involved in the execution of the computer's directions.

Planning computer work

Let us now consider some of the attitudes we should adopt in planning the work to be undertaken by a computer which is in partial control of a business. The first point perhaps is that its control can only and should properly only be partial. The management must inevitably have the last word, for the rather obvious reason that the computer cannot be instructed what to do in *every* circumstance that is going to arise. In the nature of things it can be told only what to do in those circumstances someone was able to think of, and even to cope with all of those usually means a bigger programme than can be handled.

The next point is that the programme must take full account of the possibility of things going wrong. The number of such possibilities is very large indeed in practice, so that not all can be considered; on the other hand the probabilities of certain kinds of error are far larger than others and therefore much experience and study of actual errors and practical difficulties is called for. Only those which are going to cause a significant amount of wasted time and effort need be planned for. Probably the failure to plan for the inevitable errors by all concerned has been the chief reason for the failure of

Fig. 3 Leo I, the first electronic computer in the world specially designed for office work and the first to be put to work on a daily schedule in January 1954. This machine has multiple input and output channels with buffer storage on all channels and automatic conversion between binary and decimal or sterling notation

Fig. 4 A typical modern installation; a Leo II computer installed in the offices of a well-known British steel company. The extensive and flexible monitoring and general control facilities are conveniently grouped on the console

computers to achieve the more ambitious aims forecast for them in the recent past.

Yet another point is to make the procedure for the computer to carry out as all embracing as possible and to reduce to a minimum the number of separate jobs on it needed to accomplish the entire task. In this way not only do operating and machine errors have less chance of interfering with work, but what is more important, valuable statistics or analytical surveys can be made, often for negligible extra cost in time or effort. When calculating a payroll the computer can readily be instructed to report the men who are persistently late or working extra long or short hours, or the department which is doing a high proportion of overtime or has an abnormal amount of sickness, and so on (*3*). Again, it can be told as part of the data just how serious the lateness or sickness has to be before any report is printed and the criterion can readily be varied at discretion. Thus management is spared having to look at figures which show that all is well and need only examine the exceptions.

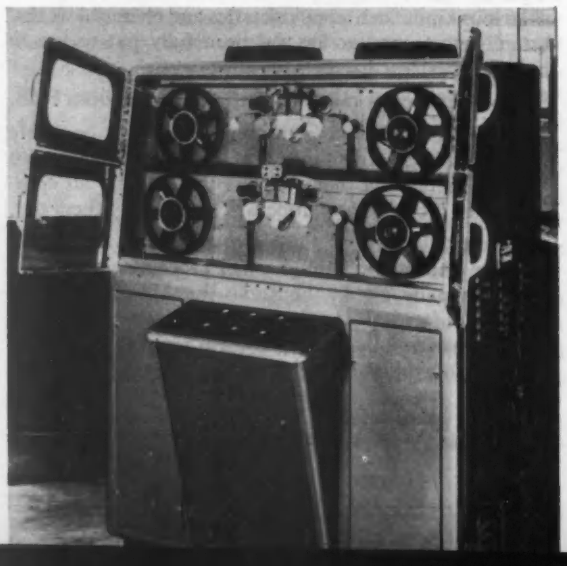
Control of stores

To take another example, consider the problem of controlling large stocks in a central store, often so heavy a clerical task that it is very imperfectly carried out. First of all the computer must record all issues and receipts and keep check of the quantity of all stocks; it must account for the stocks in money terms allowing for possible variations in price. Then it must give warning when stocks of any item have fallen below the prescribed re-ordering level. So far it is only doing more cheaply and quickly and probably more accurately what may previously have been done using a punched-card system. But a computer can do far more than this. It can take account of the fluctuating demand and the varying size of individual withdrawals, and of actual and probable delivery delays on orders for new stocks, and it can work out the best possible moment to replenish stock, and the proper price to charge for withdrawals and so on. It can draw attention to slow-moving items and forecast price trends. It could, if desired, work out the most profitable way to lay out a given sum of money on stores to meet future demands following the trend of demand shown by current orders. Thus by introducing the computer into the organization of stores one is closing a feedback loop, since the errors, i.e. the failure to maintain stocks at proper size, or to charge enough to cover replacement costs plus interest, etc, are fed back into the computer, which can indicate clearly the human action needed to correct the situation (see Fig. 2). It is easy to go further than this and report when the human action called for is not taken.

Rethinking the business structure

Many people consider that it is the opportunities which computers offer for thus skimming the cream off the information being processed which will make them of the greatest value to business. Though a start has been made on applications of this type the larger part of the benefit has certainly yet to be obtained. It is interesting to consider why this is so; it can be said at once that it is only in part the fault of the computer; it is chiefly the fault of those who might use it. It demands an unusual effort of the imagination together with a lot of experience to frame the tasks to which a computer should be set. Perhaps this is why in some quarters—particularly in the USA—it has been popular to advocate, as a first step to introducing a computer, that firms transfer their office work to punched-card machinery, because in doing so useful systematization must be introduced (*4*). This would then, it is argued, facilitate the writing of programmes for the eventual introduction of the computer. Cynics might say that such a view is of real benefit only to the suppliers of punched cards. It certainly seems to be the case that the clerical applications for computers developed in this way tend to be of restricted scope, since the limitations imposed by punched-card machinery tend to be reproduced quite unnecessarily in the computer programme when it is eventually written. In this country there is wider appreciation that to get the most from a computer the whole activity of the business ought to be analysed afresh from first principles. Unfortunately the scale of the effort required to undertake all of this task seems to have deterred some businesses from trying to do even a part. Experience in Leo Computers over nearly five years with first one and later two computers devoted mainly to commercial clerical work has shown how worthwhile it can be to take over some quite routine tasks (*5*).

Fig. 5 A Decca magnetic tape transport adapted for use with Leo. Two heads are fitted so that all information written can be automatically checked as soon as writing is completed. Two independent units are mounted one above the other in the same cabinet



The importance of analysis

Before any programme can be written for the computer therefore the nature of the problem to be tackled must be stated in detail and as explicitly as possible. Oddly enough this is a most difficult thing to do; asked in general terms what information they lack, offered in fact a genie who will—free of charge, for no effort on their part and in no time at all—provide any facts or figures they care to specify to enable closer control of the business to be achieved, managers usually fall back on the prescription, 'As before only more so'. Experience gained in analysing successfully diverse business problems is therefore vital and justifies the emergence of systems analysts (who are also skilled computer programmers) as a new profession. The writing of the programme itself, though important and demanding considerable skill and knowledge, is nevertheless secondary to the preliminary analytical task.

As more and more experience of such analyses is obtained, so will there tend to be more varied ways of examining the different situations arising in a business. Corresponding to these new concepts there will probably arise entirely new types of accounting and control procedures, ones in fact which even had anyone thought of them could not have been carried through either sufficiently quickly or sufficiently cheaply before the advent of the computer.

Human control of the computer

It goes without saying in putting a computer into a business to exercise control that someone must control the computer. As will appear, many persons will in fact be involved in controlling it, and what they do is quite as important as what the computer does.

We have seen how in any control system there must be built-in means for detecting and for correcting errors. Management of a computer involves, as far as possible, preventing mistakes from happening, detecting when they do happen and taking prompt corrective action. All this will be more efficiently done if the different possibilities of making mistakes are recognized in advance and staff trained to act appropriately. The operation of a computer is liable to errors arising from:

a. Faulty programme instructions

b. Faulty data

c. Faulty operation

d. Equipment faults.

To verify that programmes are right it is becoming standard practice to run trials on dummy sets of data and compare the answers obtained by computer with those obtained by other means. Next, the job if a clerical one will be run in parallel with the office for a week or two. In most cases the office is found to be wrong more often than the computer. Nevertheless there usually are one or two errors in a programme of any size. Thereafter there is no difficulty in making certain by suitable input checks that the programme is correctly read and stored by the computer each time it is used.

Faulty data are still a common cause of error and of delays, though a great deal can be done to reduce their incidence and minimize their effect. Brought-forward

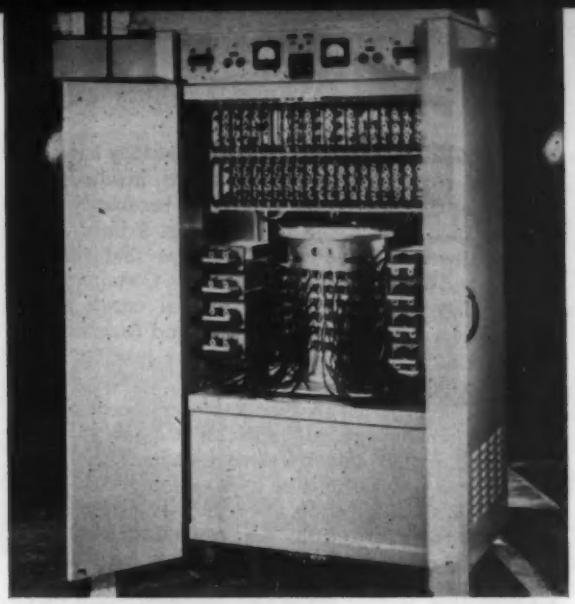


Fig. 6 A Ferranti magnetic drum cabinet. One or more such drums are often used to increase the storage capacity of the main storage systems of large computers. This drum is capable of storing up to 8192 numbers of 40 binary digits each (equivalent to about 12 decimal digits), and the cabinet includes electronic circuits for amplifying the read signals and synchronizing rotation of the drum with the computer

data can have check totals associated with them, and the punching of all current data can be verified whether on cards or paper tape by using one or other of a number of commercially available verifying machines (*6*). On a purely random basis of assessment the likelihood of both recorder and checker making the same mistake is very low. In practice it may be found to be higher than this often because of misleading features in the design of a clerical form. Purely mechanical errors in reading correctly recorded data can be avoided only by good engineering but they can at least be detected by so-called *parity checks*. In one such form of check the number of holes on a row in a piece of punched tape is always made odd. One more position must be used than is otherwise needed to convey the information; thus if six positions (expressing in code $2^6=64$ possibilities) are needed for an alpha-numeric character,* a seventh position must be added for the parity check.

This simple system does not allow for automatic correction of the error; such action usually has to be taken by the operator. Generally this will involve going back and doing the job, or part of it, again. In minimizing wasted time great importance attaches to making such restarts easy; provision for them at intervals during the run of a job is now a feature of all well-constructed clerical programmes. Detailed discussion of the programming techniques involved is outside the scope of this article, but it is evident that the computer must be made to record at intervals figures expressing the state of the job to date. Furthermore there must be some means for either the operator or the computer to run back the data tapes or cards to the appropriate points for a restart. Such means may be either manual or automatic. Plausibility and self-consistency checks are also valuable ways of proving data before proceeding with the calculation proper.

Similarly checks can and should also be applied to results. Those which are recorded on cards or tape can

* i.e. a character that can be a letter or a figure.

be read back automatically to prove that they have been correctly recorded. Such checks are invaluable by eliminating time wasted repeating work because brought-forward data were found to be wrong. Printed results are usually scrutinized visually to see that they are sensible and do not have figures omitted. Certain printing systems have some degree of built-in check against errors, but it is obviously difficult to read back from the results printed on the paper itself, nor has this so far been attempted.

It is to be expected that as computers become faster and more reliable one will be left to face only the faults introduced in the data by some human error. It will then become very worthwhile to devise automatic means of carrying on with the job, either by making a plausible correction to the erroneous item of data, or omitting it and passing on to the next. There is scope here for great sophistication but the field has only begun to be explored.

At the same time the engineering features of the computer must be made as reliable as possible and those faults which do occur must be found quickly. Experience has shown that electronic designs which permit of all components, valves and power supplies drifting simultaneously to the extreme limits of their permitted tolerances are in practice very reliable. Well-designed computers are now engineered throughout in this way. Introduction of transistors is generally expected to give an improved standard of reliability, though as yet there is not much practical experience to prove this.

When computers do fail they generally do so for one of four reasons:

1. The mechanism of an input or output device fails.
2. The slow deterioration of some electronic component causes a circuit to go outside its normal operating limits, so that it fails.
3. An electronic component suddenly fails without warning.
4. There is an intermittent failure, i.e. the internal electrodes of a valve occasionally touch or a soldered joint on a wire becomes 'dry' and makes intermittent contact.

In case **1** the presence of the fault is generally obvious, and the standby machine can rapidly be brought into service. In case **2** the regular use of 'marginal' methods of checking, such as are incorporated in Leo (7), will give advance warning of impending trouble so that it can be prevented, long before the deterioration has become sufficiently severe as to cause wrong results on a job of work. Case **3** calls for the rapid and accurate investigation of the fault by the engineer. Very seldom does the trouble take over half an hour to clear. Case **4** presents the greatest difficulty; if the fault cannot be provoked at will it may be difficult to find. This is where the control of accuracy of the results is important; if the intermittent fault occurs very infrequently, say only once in several hours, nearly normal working can continue with negligible risk of passing out false results. Naturally computer designers are continually seeking improved constructional techniques to eliminate intermittent effects. It is also true that valves are one of their commoner causes so that the introduction of transistors will give an improvement.

A well-maintained computer can nowadays be expected to function correctly for better than 95 pc of its scheduled operating time (not including, that is, time deliberately set aside for routine maintenance procedures). Owing to repeats arising from faults, data errors and accidental misoperation, and to time lost in change-overs between jobs, the actual productive efficiency varies considerably. In badly run installations or where there is insufficient work, it can be under 10 pc; in good cases it will exceed 70 pc. There is certainly a need for good management in getting the most work out of a computer and this is now becoming more widely recognized.

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2 Digital computers in the factory

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Views on some of the general problems of computer control

MY TITLE MIGHT INDICATE ONE OF TWO THINGS TO THE reader, depending upon his primary interest in computers in relation to the factory. One of these is, of course, the use of a computer for the automatic control of machine tools and processing equipment; the other is its use for data-processing within the factory organization. Both are

aimed primarily at increasing the measure of control achievable, the one over the machine tool; the other over the factory as a dynamic integrated organization. Here I shall discuss the second of these two fields.

The concept of total factory control

Before considering what computers can, in fact, do to improve control in the factory, it is worth while thinking about what needs to be controlled and where an improvement in controllability is desirable, for clearly the use of expensive computing equipment must be reasonably justifiable economically. Once we leave behind us the conception that a factory is merely a heterogeneous collection of machine tools and assembly shops and start to think of it in its true sense as a complete organism, we immediately note the enormous amount of calculation, assessment, decision taking and evaluation that goes on in production planning, budgetary control, works accounting and production control. I think we must also recognize that, whatever benefits we seek to achieve by the use of a computer, the most worthwhile ones do *not* involve a reduction of clerical staff.

Increasing complexity of industrial life

It is an oft-stated truism that industry is becoming more complex. This means not only that we are using more complicated and wonderful pieces of machinery, but also that we are creating more complex organizational and communication problems. The controlling of these aspects of a factory's operation can be measured in such concrete terms as those which are used to express the value of stock-holdings and work-in-progress, and of the factory's ability to adjust itself to changing demands—to do that and to operate normally at minimum cost. It is only necessary to compare the accuracy used to measure a component made in a factory with the accuracy of production planning to realize that controlment of technology is far advanced beyond that of planning and communication within the factory. Logically, the higher the accuracy used to measure physical dimensions, commensurate with the ability to produce these dimensions, the more nearly we may expect a finished article to correspond with its original drawing. Surely, therefore, we may expect by analogy that, through accurate measurement applied to the overall control of a factory, the completed production plan will correspond more nearly to the same plan as originally envisaged. This desirable advance implies, first, accurate measurement and, secondly, the means to employ this measurement directly to increase controlment.

The importance of time

The one essential element of any dynamic production plan is the accurate relationship of each element of data to time, and in this sense there is a difference between the two halves of our analogy above. For, in setting the standards of accuracy for the manufacture of a component, time is of little importance, while the time required for the data-processing involved in the control of a communication system, and indeed in the planning of such a system, must be a minimum. I suggest, therefore, that the digital computer may enable an enormous

Fig. 1 Data on stocks, raw material, piece parts, plant loading, etc can be processed by a computer to enable the production manager to take necessary action

stride forward in organization control, and that many things which hitherto have been regarded rather as esoteric exercises may now be regarded as common-sense applications. Moreover, these applications may prove of tremendous economic benefit, and this as a direct reflexion of an increase in control rather than of a decrease in clerical staff.

Lest it be considered that the subject concerns purely the accountant or production control manager, I must stress that improvements in data-processing control lead to substantial advantages in technological control because the results of such work can guide the factory manager to assess more accurately his planned requirements; the tool room manager to establish more realistically his optimum requirements for small tools; the plant engineer to plan better the maintenance of equipment—particularly the overhaul of machine tools, where this involves their being taken away to the millwright's shop for a month or two. Although, for convenience in the modern factory organization, all activities are in departments and each manager has his own responsibilities, clearly activities must be accurately correlated if the factory is to be an efficient production unit. Measurement and communication, whose study has often been neglected owing to the inherent time difficulty, are indeed the key to such correlation.

Production control

While, at the beginning of the article, I cited several activities offering scope for an increase in controlment within a factory organization, I suggest that the one most likely to benefit from study is production control. This most intimately reflects the activity of the factory itself and is, perhaps, most directly concerned with the physical elements of production. What we really seek in improving

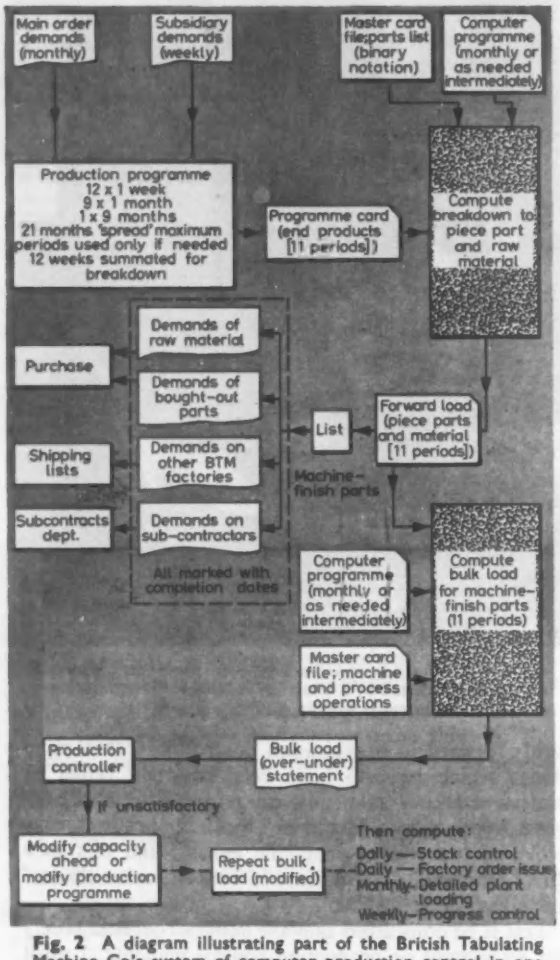

Main order demands (monthly)
Subsidiary demands (weekly)
Master card file;parts list (binary notation)
Computer programme (monthly or as needed intermediately)
Production programme 12 x 1 week 9 x 1 month 1 x 9 months 21 months 'spread' maximum periods used only if needed 12 weeks summated for breakdown
Programme card (end products [11 periods])
Compute breakdown to piece part and raw material
Demands of raw material
Purchase
Demands of bought-out parts
List
Forward load (piece parts and material [11 periods])
Shipping lists
Demands on other BTM factories
Machine-finish parts
Subcontracts dept.
Demands on sub-contractors
All marked with completion dates
Computer programme (monthly or as needed intermediately)
Compute bulk load for machine-finish parts (11 periods)
Master card file; machine and process operations
Production controller
Bulk load (over-under) statement
If unsatisfactory
Modify capacity ahead or modify production programme
Repeat bulk load (modified)
Then compute:
Daily — Stock control
Daily — Factory order issue
Monthly — Detailed plant loading
Weekly — Progress control

Fig. 2 A diagram illustrating part of the British Tabulating Machine Co's system of computer production control in one of their Letchworth factories

the control of an organization is increased productivity through higher efficiency and lower operating cost; by the use of a digital computer in certain data-processing functions relevant to production control, I believe that substantial progress may be made towards these ideals —which are the *cri de coeur* of industry today.

It is indeed surprising to find how often the most laborious clerical routines are—and have been for years —accepted as essential. No further thought is given to the periodicity of calculations as a routine and the responsiveness of the actions they generate. These two latter aspects are, of course, the very essence of control. In fact the wretched job takes so long to do that everybody concerned is markedly reluctant to do it more often than absolutely necessary, or, if considering improvements, to seek further than the techniques of performing it.

An example is the ordering of a new production programme. Such ordering follows an agreement between the production and sales units on the content of the programme and effectively throws a peak load—which may last one month, say—onto the ordering department. If this job is undertaken four times a year, there would be a marked reluctance to accept any changes to the programme during and immediately after the ordering procedure; moreover one effect of Parkinson's Law—that the work to be done fills the period allowed for it —is a spread of the ordering procedure over more of the three months between any two programmes than was originally allowed (one month).

These situations take time to develop but a stage is reached when ordering cannot readily be completed before the next production programme is released. The normal reaction is to seek mechanized data-processing as a solution—looking not to the real problem, but to the effect. The real problem may be posed as (a) 'How often should we do this ordering job to ensure minimum stock-holding and order placement, consistent with maximum availability?' and (b) 'How quickly, without invoking financial penalty, can we change our minds to meet demand changes?'. The answers to these questions may well be that (a) the job should be done twelve times per year, and (b) it should be completed always within one week of the release of the programme. Regrettably, one more often finds that the problem is stated as 'How can we be sure of getting all our ordering done within the month allowed?'.

The attitude of resisting extensive changes in procedure is endemic, but understandable, for to consider objectively elaborate and lengthy routines when one is closely concerned with compiling them is most difficult.

Improvement in the routine

Therefore, prerequisites of achieving realistic improvement in such a routine are first, that means are available for substantially reducing the time involved, and secondly, that it is no longer regarded as a routine. We must go further back and try to envisage the total requirements of a control system if we are going to benefit truly from the enormously superior processing speed of a digital computer. In fact, we must be able to think about the needs of a control system untrammelled by what has always been. In addition, we have to be careful not to allow the known characteristics of a particular computer to restrict us, for this can be almost as dangerous.

However, we should not forget that we shall be using a *digital* computer, which always implies simple arithmetic. This is appropriate, for our increase in control must rest upon the ability to note all items of data in relation to other items, and to do this at high speed. Even for a major data-processing job such as plant loading, the periodicity gives at once a measure of the feedback.

The production programme

I now turn from general considerations to specific problems arising in production control. All production starts with an order, whether this is a sales programme, a particular customer's order, or managerial sanction to continue an established production of a mass-produced article. The first task of production control is to ensure that all basic data on the products of the organization are known and accurate. This, of course, is a sweeping statement, for there can be few organizations which do truly possess the accuracy they like to think they do; calculation quickly establishes that the number of separate data involved in a quite small organization normally runs into millions. However, if we are increasing controllability, we must increase the accuracy of the measurements used. In practical terms, this is possibly the most onerous task involved in the establishment of a system

of computer production control. Once the system is established, however, with its increased sensitivity, maintenance of valid basic data is undoubtedly far easier than before. Moreover the production control department can then tackle its initial problem of expressing its order, programme or sanction in terms suited to the factory activity; in other words, the standard problem of production programme breakdown, the expression of a programme in terms of quantities of piece parts, of subassemblies, and of raw materials.

It is not always appreciated that this task of production programme breakdown is a direct part of the production cycle, for it follows the receipt of authority to manufacture and precedes direct activity in the ordering or manufacturing spheres. Nothing can be done practically until the job has been completed. Again, it is not unusual to find that some weeks are allowed for its completion, and this period of time is sheer deadweight added on to the normal factory production cycle. But the job in fact is one of simple data-processing, and a computer can radically reduce the time involved in handling it. In my experience, this reduction might be, for example, from 5½ weeks to two days, with a relatively simple and inexpensive computer. Moreover, the computer can, of course, not only be used to establish the gross exploded demand for each piece part, but in the one operation may relate this to current balances and produce the net requirement, taking into account limiting data such as minimum ordering quantities and optimum batch sizes.

The digital computer as a simulator

It is perhaps worth mentioning that often even the smallest computer may be of substantial use in the compilation of the production programme itself, which after all has to conform to certain limitations. The computer, used in the sense of a simulator, can determine the suitability of a given production programme for the capacity of the factory required to undertake the programme. The speed is such that, in its broad terms, the programme may almost be tailored to the factory's requirements, or a precise statement prepared of the additional capacity required to suit a particular programme.

Again, in considering this problem, we must bear in mind that while some change faster than others, all programmes are subject to changes which rarely can be counted in terms of months; far more often does one hear quoted the number of changes per week or even per day. In truth, if *all* changes are considered, the changeability of a production programme is rapid, for undue scrap, short-notice spares demands, and design changes, equally have some effect on a production programme as do changes imposed by the original authority. One must always keep in mind the concept of the programme and indeed of the factory itself being complete entities. The slightest change to a part of a programme affects, to some degree, the whole.

The control of stocks

We consider, as the next major aspect of production control, the activity generally known as stock control. More often than not, this is taken to mean a historic recording of the movements of items of stock and the resultant balances that these movements generate. If stock control, as such, is to be of benefit, it must cover what is going to happen rather that what has happened. But the volume of arithmetic involved increases almost in direct ratio to the number of future periods considered. Once again, however, the computer comes to our rescue: not only by enabling us to consider quite comfortably almost as many periods ahead as are required to ensure that nothing may go astray without sufficient prior notice; but also by providing us with the necessary information about any tendency to go astray. If, indeed, we plan to issue one hundred nuts from our store in sixteen weeks' time and we have one hundred nuts planned to be available for issue in sixteen weeks' time, we do not need constant reminders of the fact from a computer. We merely need to know today if there are planned to be only ninety-five nuts in the store in sixteen weeks' time. In my experience, such a stock control system, involving ten periods of time forward and up to some seventy separate items of information on each part concerned, may, in a medium-size factory, be processed by a small computer in some forty-five minutes per day. Here we have a firm measure of control, for we have the essential element of time on our side—we shall always have sufficient warning to avert an undesirable stock position; this may imply undesirable excesses as well as shortages. Moreover the output information can be engineered to be concise enough for the production control manager himself to read and direct appropriate action.

Feedback

In a stock control system, accurate data are extremely important: both original data and consequential data, i.e. feedback data recording performance. Very much within this framework of stock control is direct control

Fig. 3 A combined drawing and layout, and a computer-produced operation card, is clipped to each machine's drawing stand in this computer-controlled factory

of manufacture, for all variances in the original plan may be fed back, and the computer, which considers all the factors, produces an appropriate answer. One may cite here the example of scrap. An order may very well have been raised some weeks before a date on which scrap is produced, and it does not necessarily follow that on this date an immediate replacement order should be issued to replace the scrap. Other factors may well

have changed and should be weighed—which a computer can do simply and rapidly—before a decision to replace is made.

Sequential plant loading

There is no logical order for considering the various aspects of production control, for their integration implies overlap and continuity, but I shall deal next with plant loading. In the best correlated planning departments it is axiomatic that there exists an optimum sequence of operations for changing a piece of raw material into a finished component. Any consideration of a particular output in a certain period from a complete factory should imply an equally optimized sequence of manufacture for each of the many pieces and assemblies in relation to one another and therefore for all the individual operations which go to produce each of them. Almost certainly the mathematical task of establishing this optimum for any moderate-size factory is beyond the scope of any existing computer in the time allowable for such computation; thus the number of variables makes the task, in the light of our present knowledge, insuperable. However, we need not despair, for in any system of control there must be compromise. This may be implied purely by the limits of measurement or by the accuracy of the measured interrelation between the system elements.

The importance of timing

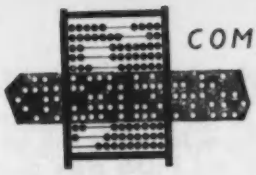
The great problem with plant loading arises from the time element, for one must fully take into account the individual sequencing of operations to realize the optimum use of plant. For the advantages of being able to cut the right piece of metal at the right time in relation to a given production programme cannot be overemphasized: they signify the vast difference between the miserable condition of having excessive stocks of certain parts but shortages of others and the happy condition of having just sufficient of all stocks. This, of course, applies to those organizations where the policy is to use all the equipment all the time, or at least to get as near to this as practicable. The elements of the problem are fairly simple. One must know the capacities of the various groups of machine tools and assembly shops within the plant in relation to each of a number of periods of time; and one must have all the processing information in terms of time and sequence and be able to relate them in near optimum fashion without long calculation. The difficulty of knowing which orders one must offer up as load to the available capacity in sequence can be reduced by proper consideration of their relative urgency for completion and their complexity. These two prior factors may be evaluated on a time basis, and this enables the derivation of a sequencing factor which can be regarded almost as a constant for plant loading. The total programme is next balanced against the capacity of the plant. Then prior to the detailed plant loading of the succeeding period, we have already established within reasonably narrow limits the feasibility of the relationship between load and capacity, and we can produce operation documents detailing the load to the extent of some 90–95 pc of the available capacity in the succeeding period or periods, with every expectation that this will be achieved.

A glance at the near future . . .

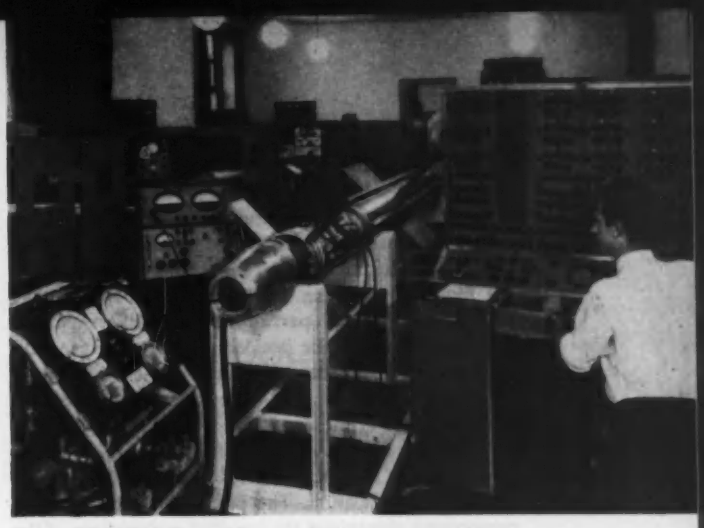
What is then the future for the digital computer as a data-processer in the factory? To date, there is probably only one factory in this country operating an integrated system of computer production control, the Letchworth 1B factory of the British Tabulating Machine Co. This is a small light engineering factory employing approximately 400 direct operatives and 100 indirect operatives engaged in the complete manufacture of a range of about 100 end products—coils, relays, plugboards, cable assemblies and the like. There are some fifty different types of machine tool in use and twenty specialized assembly groupings and the throughput time involved in the mainly batch-production work is nine weeks. This factory is being used as a 'guinea pig' by the BTM Co before extending the system of computer production control to its other and larger factories. The decision to go ahead has already been made and the company's main Letchworth Factory will be embraced by the system by mid-1959 and its Northern Ireland group of factories by early 1960, two Hec 1201 computers being used. There is no doubt whatever that this concept of improving control by recognizing the totality of a factory organization will spread. It will not be confined to the perhaps rather 'easy' example of light engineering—'easy' in the sense the project might well take two years to bring to fruition—but will be used in heavy engineering, textiles, process industry, food manufacture, and many other types of industrial activity. But what has so far been done is only a start within the factory organization: we have achieved a greater integration of communication with the physical activity going on in the factory, and next we must achieve the rather more tenuous but none the less important correlation of budgetary control, factory accounting, costing, contractual purchasing, and the like. The optimizing of these functions stems from the optimizing of the physical activity.

. . . and the not-so-near future

Looking further into the future, I consider that much of this data-processing work will become redundant, for the greater part of it is made necessary by the inclusion of man as an integrated part of factory organization. As man gradually fades from the scene, the need for much of the elaborate data-processing, so necessary now to effect better control, will fade also. However, this concept of the automatic factory, while indubitably something that will come and indeed is coming, is surely a long, long way off. There must of course be an economic incentive to establishing a factory which does not employ men. In the writer's experience a single line of semi-automated plant which reduced the total operating manpower required from 31 to 7 cost initially £240 000, even though certain existing plant was utilized. The noticeable trend in some industries to a greater concentration of productive power in one place and the reduction of product variety (at least at the unit stage) does indeed lead to active consideration of automation, but it may be 25–50 years before use of man as an integral part of the production unit is reduced to, say, one-quarter of its present level. Meanwhile, the means to vastly improve control of many activities which are so truly a part of factory organization, yet not directly the manufacture itself, are available.



COMPUTER SECTION



The author introduces, in the first of two instructive articles, the methods used in simulation and illustrates their use in analysing a simple feedback control system

Analogue simulation in system design

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1. BASIC CONTROL PROBLEM

THE APPLICATIONS OF FEEDBACK CONTROL SYSTEMS HAVE increased rapidly during the last decade in all branches of science and technology. The diverse nature and ever increasing complexity of tasks to be performed has resulted in a need for machine aids to assist the analyst and designer in evolving the required system. The use of simulators is now becoming a standard technique and it would seem appropriate at this stage to outline the general concepts of feedback control system design and to pin-point the particular need for simulation.

Owing to the wide range of application of feedback control systems, it is difficult to formulate precise methods of analysis and design. However, in most cases, the problem resolves itself into four basic steps.

1 Preliminary study of the specification.

2 Formulation of a mathematical model(s).

3 Selection of a particular model based on practical consideration of the specification.

4 Analysis and simulation of more detailed aspects including non-linear effects.

The boundaries between the above stages are far from rigid and a more detailed consideration of each stage might be helpful.

1 A specification is given, generally in non-analytical terms, outlining the desired static and dynamic performance of the system, or in other words, the task with which the system has to cope. A simple example would be the automatic positioning of a machine tool on a work table, to a particular accuracy and within a prescribed time from the instant of arrival of the information at the input to the system. The specification is interpreted as far as possible in analytical terms, i.e. required bandwidth or in terms of transient response and steady-state accuracy, for a particular form of input demand. In this way the specification can be considered as imposing restrictions on the mathematical functions describing the characteristics of the system. Mathematical models of the system are thus derived in the form of a set of differential equations or as block diagrams showing the essential linking together of the component transfer functions. The latter, in general form, are expressed in respect of a component, as a ratio of the Laplace transform of the output to the Laplace transform of the input, in terms of the complex variable s ($s = \alpha + j\omega$). With zero initial conditions, s may be regarded as the equivalent of $p \equiv d/dt$. For ease of analysis these models will be essentially linear and may be regarded as a simplified mathematical abstraction of the actual system. It should be noted that results from these linear models should be regarded with extreme caution as the linearizing assumptions adopted in their formulation may not be easily justified. It is assumed in this context that the relevant non-linearities such as saturation, backlash, hysteresis, etc, which would be included in the formulation of a more realistic model, are of an incidental nature. In those systems where deliberate non-linearities are introduced as a feature of the proposed design, a linear model is obviously not possible.

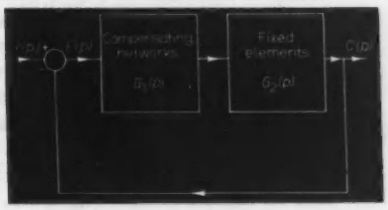


Fig. 1 A simplified block diagram of a general mathematical model of a feedback control system, where $C(p)$ represents the controlled variable; $E(p)$ the actuating signal $[R(p) - C(p)]$; $G_1(p)$ the transfer function of compensating components; and $G_2(p)$ the transfer function of the fixed components

2 A number of systems based on different mathematical models may be derived, each of which fulfils the analytical specification. This step is extremely important in many applications as it generally provides a fuller appreciation of the fundamental aspects of the system and the task which it has to perform.

3 One system is now selected on the basis of practical considerations of the specification. These include the numbers and types of components suggested by the different models. The relative ease of construction of these components and their range of performance under the required operating conditions may be overriding considerations. Again part of the proposed system may be available or may be decided on economic grounds. Components in this category may be described as fixed and might include the type of power supply and output power element or motor.

The choice of the overall system is therefore governed by two main factors, the fixed components and the analytical specification. The performance of the fixed components determines the required performance of the

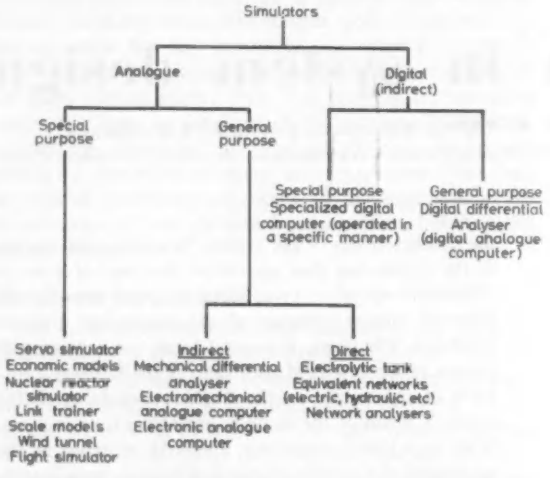


Fig. 2 The classification of simulators is not rigid and only a few examples have been included under each heading

remaining components or compensating networks, so that the system meets the analytical specification. A simplified block diagram of a general mathematical model is illustrated in Fig. 1. Analysis of this model operating in a linear fashion is usually straightforward. The determination of $G_1(p)$ may not follow a rigorous mathematical pattern because of the number of variables involved, and graphical aids are usually employed, such as Nyquist diagrams, Nichol's charts or root-locus plots of the closed-loop poles and zeros.

Again in those systems where the reference input can best be defined in statistical terms, statistical analysis may be employed. However, whatever the method adopted the result can usually be obtained in a logical manner in a reasonable time.

4 Having determined the system components on the assumption of linear operation, one must now consider the relevant non-linearities, which may be intentional or incidental. The latter are inherent in the system and include saturation, dead zone, backlash, transportation lags, temperature and ageing effects, etc. Deliberate non-linearities are those which are considered an essential part of the design. For example the power rating of components may be considerably reduced if allowed to operate under saturated conditions for a limited period, compared with that required for linear operation. Analytical techniques for dealing with non-linear effects are available and include phase plane analysis, describing function analysis, convolution methods and statistical methods (*1*).

However, in most cases this analysis is an extremely tedious task particularly when a wide range of operating conditions has to be considered. In many applications this task is in fact beyond the mathematical capabilities of the designer or alternatively the calculations are so protracted and time consuming that they could not be attempted without machine aids. The latter may be numerical computers such as the desk calculator or digital computer. Another machine aid is the simulator which is essentially a physical representation or analogue of the mathematical model of the system. The use of simulation techniques has proved to be of such importance that it is now established as an essential step in the formulation of the final design. It is with the broad concepts of these techniques that this paper is concerned.

2. REVIEW OF SIMULATION METHODS

2.1 General remarks

For the purpose of this paper simulation is defined as the representation of a system, by a dynamic model or 'analogue', so constructed that it gives useful information about the system. The term 'analogue' implies that the analogous model and the system which it represents will have essential similar properties, so that an investigation of the performance of the model serves as a guide to the performance of the actual system. These essential similar properties are the mathematical parameters and equations defining the performance of both the model and the actual system.

Perhaps the most versatile means of constructing such a model is the general-purpose analogue computer, in which the variables of the relevant equations are represented as continuous functions of the independent variable 'time', in the form of voltages, displacements, rotations, etc. Where the system operates in a continuous fashion the use of the analogue computer as a simulator is a logical choice. However, in some applications such as sampled data controls or

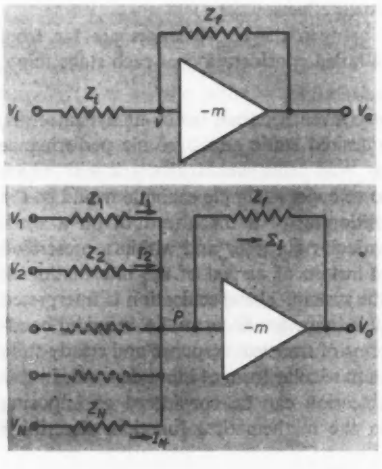


Fig. 3 Integration with respect to time (a) and addition/subtraction (b) are performed by negative-feedback high gain computing amplifiers

pulsed radar systems, a digital computer provides a more realistic simulator, provided it can be appropriately programmed and that the digital computing periods are fast enough to simulate the sampling rate. In other applications hybrid simulation involving analogue and digital techniques (*2*) may be used with advantage to give a more realistic representation especially where accuracy considerations are of primary concern in parts of the system.

Essentially the digital computer performs sums in simple discrete steps (digits) using 'on-off' devices, whereas the analogue computer draws a graph and uses continuous variables. The accuracy of the analogue computer is thus dependent on the accuracy of performing the various mathematical functions and is adversely affected by changes in component parameters.

The graphical representation of system performance given in the analogue computer is however an extremely useful facility to the system designer since it provides him with a means of understanding the physical behaviour of the problem. Moreover, the effects of changes of system variables are apparent and critical factors may be assessed.

On the other hand, the digital computer may be made to any desired accuracy, as it may be regarded simply as an automatic device capable of performing mathematical operations usually by a process of iterative additions and subtractions. Because of this method of solution, the various mathematical functions must be reduced to simple arithmetical operations, i.e. programming of the machine is required. Although the time duration of each digit is extremely short (order of microseconds) the digital computer operating in a series mode is relatively slow, because of the great number of digit movements to be performed even for a simple problem. In general it is not fast enough to simulate a system, on a real-time basis, and it cannot normally be used in a simulator in which actual physical parts of the system or a human operator are component blocks of the simulated control system. More detailed considerations of digital computers are given in (*3*) and (*4*).

A new type of computer (*5*, *6*, *7*) has recently been introduced in an effort to obtain the combined advantages of analogue and digital techniques. This computer is the digital differential analyser, in which mathematical operations representing the performance of component blocks are computed digitally but these mathematical representations are interconnected in a similar manner to the components of the system being simulated, as in the analogue computer.

The various types of simulators are represented in Fig. 2. It should be noted that the classification is not rigid and only a few examples under each heading are included.

The special-purpose computers will not be considered further in this paper as their design is based on the same fundamental concepts as the general-purpose machines. They do provide an extremely useful tool for long-term development projects or as training aids as they can be designed to perform specific tasks, much more efficiently than the general-purpose computers at the expense of versatility.

Direct analogues refers to models in which each component of the latter bears a direct relationship to the corresponding component of the system being simulated. In many applica-

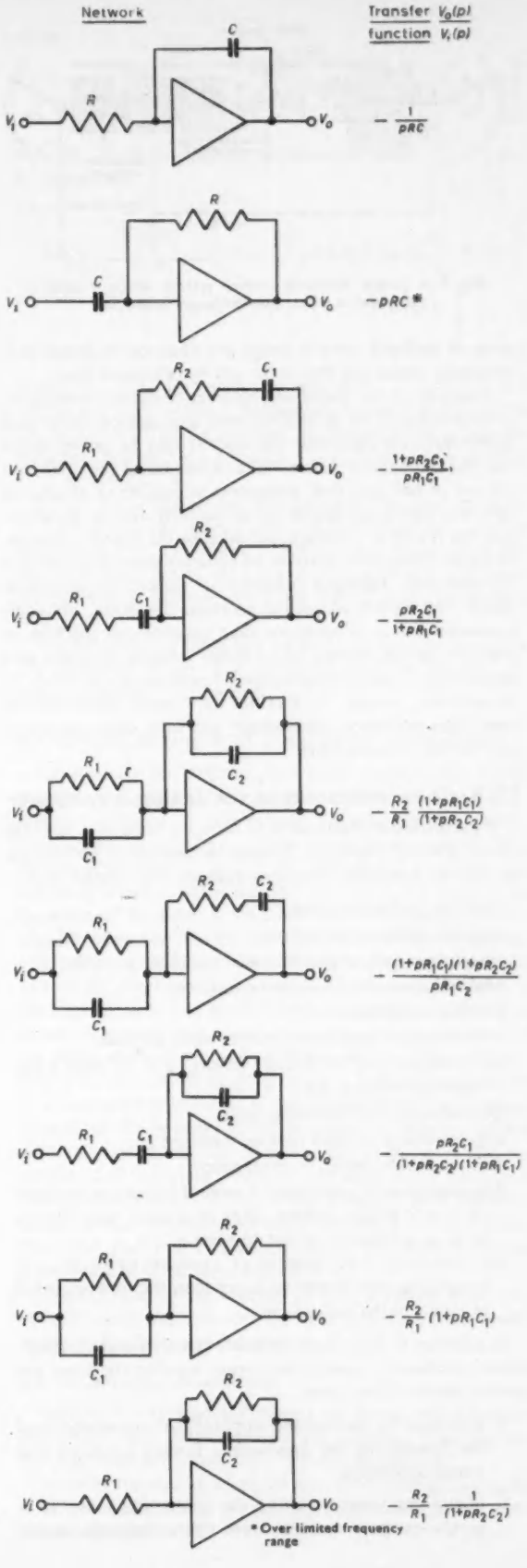


Fig. 4 A few typical transfer functions and the networks which can be used to simulate them

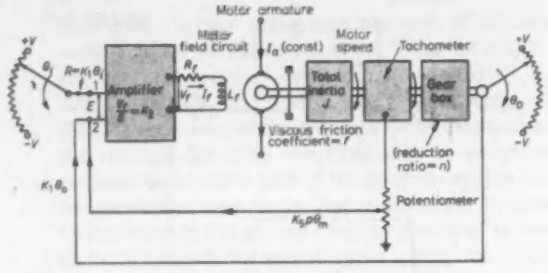


Fig. 5 A simple feedback control system which is used in the text to illustrate simulation techniques

tions of feedback control design this direct correspondence is extremely useful and this point will be illustrated later.

Attention in this paper will however be mainly confined to consideration of the general-purpose analogue computer and particularly the electronic machine. It may be briefly noted that the mechanical differential analyser based essentially on the use of ball and disk integrators is capable of accuracies up to five significant figures, but is relatively slow in operation. For this reason it is being superseded by the digital computer or digital differential analyser on accuracy considerations and the electronic analogue computer in respect of computing speed. The electromechanical analogue computer, although somewhat slower in operation than the electronic machine, is still in wide use because of its higher inherent accuracy and greater ease in generating complex functions of a variable. It is common practice in fact to have some mathematical operations performed electronically and some electromechanically in the same machine.

2.2 Basic requirements of the analogue computer

If the analogue computer is to form the basis of a versatile model of control systems, it must be capable of performing various mathematical functions such as those listed below:

- Addition and subtraction
- Multiplication by a constant
- Integration with respect to time or another variable
- Multiplication of two or more variables
- Division of variables
- Generation of functions of one or more variables
- Representation of non-linear effects such as dead zone, limiting, backlash, etc
- Representation of switching cycles
- Representation of dead time or transport lag
- Axis resolution (polar $\rightleftharpoons$ rectangular)
- Representation of generalized transfer functions of the form $G(p) = O(p)/I(p)$, where $O(p)$ is output and $I(p)$ is input as a function of the operator p
- Incorporation of compressed or extended time-scale, i.e. computing time slower or faster than the time sequence of events in the real system

In addition to the above facilities, certain ancillary equipment is necessary. Apart from power supplies the most important items of this cover:

1 Provision for starting and stopping the computation and for introducing the appropriate forcing functions and initial conditions.

2 Means for interconnecting the computing units. In a general-purpose machine these interconnexions should be arranged to be neatly and easily made, so that the setting-up and checking procedures are simplified.

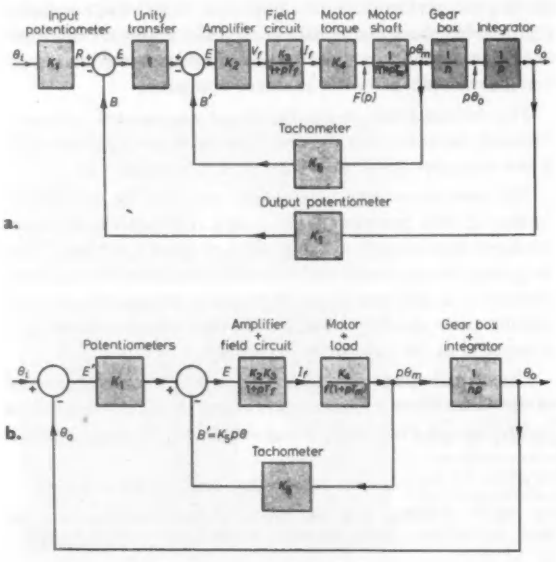
3 Monitoring facilities for checking the performance of units.

4 Arrangements for displaying and/or recording the solution.

With these facilities the computer can provide a simulation of certain non-linear systems with almost the same ease as for linear systems, and this is its most significant feature compared with analytical methods. It should be stressed, however, that logical interpretation of the results obtained is still necessary and the computer should be regarded as being complementary to analytical studies. Simulator results may confirm analytical results or indicate a possible new analytical approach and thus broaden our knowledge and understanding of new problems. Although restricted in accuracy the computer gives more reliable results from an investigation of the most complex systems compared with results (if obtainable) by analytical methods. Even in relatively simple problems involving simple non-linearities or variation of coefficients, a strictly mathematical study can become prohibitively time consuming. As stated previously the analyst is generally forced to assume some linearizing approximations which may result in a considerably higher error than that introduced by the computer. Again the computer representation can be investigated for fault conditions over a wide range of operating conditions. The information obtained from such studies is of immense value as it may be impossible from a cost point of view or danger of human lives, to investigate the real system under such conditions. The main limitations of the analogue computer are the accuracy of computation and the limited amplitude range of computing variables.

The accuracy of performing each mathematical function can readily be estimated. Typical static accuracies are in the range 0·01–1 pc. The dynamic accuracy is usually given as a phase error at some frequency or over a band of frequencies, and the significance of this error depends on the particular

Fig. 6 The block diagram (a) of a linear mathematical model of the system shown in Fig. 5 together with its equivalent diagram (b)



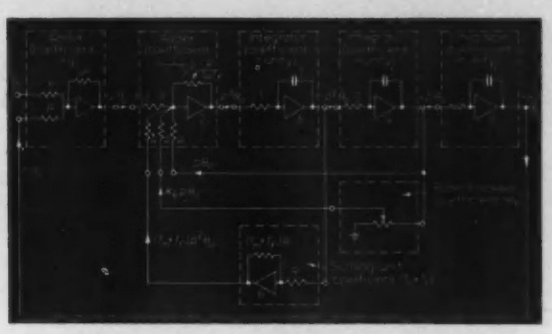


Fig. 7 A computing circuit which can be used to solve the differential equations describing the performance of the simple feedback control system

time scale and arrangement of computing units for the problem. No general statement can be made regarding the overall accuracy of a particular computer, since the accuracy depends on the interconnexions used for each particular problem. Experience indicates that if static accuracy of the order of 0·1 pc is obtained in each unit, the overall accuracy will be the order of a few per cent (slide rule accuracy) provided that the computing frequencies are well within the operating range. With regard to the restricted range of amplitude of computer variables, three decades are generally included. This restriction can be overcome by a series of solutions in which final solutions for one act as initial conditions for the next, until the desired range is obtained. It may be noted that for the solution of linear differential equations, only three types of computing unit are required to perform the fundamental mathematical functions—integration, scaling by a constant, and addition/subtraction.

Integration with respect to time and addition/subtraction are performed with use of negative-feedback high gain computing amplifiers.

Referring to Fig. 3(a) if m denotes the forward voltage gain and it is assumed that the input current and phase shift of amplifier is zero,

Then

$$V_o(p) = -\frac{mZ_f(p)}{Z_i(p)(1+m)+Z_f(p)} \cdot V_i(p) \quad \ldots (1)$$

where $Z_f(p)$ and $Z_i(p)$ are generalised impedances. If m is very large

Then

$$V_o(p) \simeq -\frac{Z_f(p)}{Z_i(p)} V_i(p) \quad \ldots (2)$$

For integration,

$$Z_f(p) = \frac{1}{pC}; \quad Z_i(p) = R \quad \ldots (3)$$

Hence

$$V_o(p) = -\frac{1}{pCR} V_i(p) \quad \ldots (4)$$

or

$$V_o(t) = -\frac{1}{CR}\int_o^t V_i dt \quad \ldots (5)$$

The arrangement for addition is illustrated in Fig. 3(b) giving an output voltage $V_o(p)$

where

$$V_o(p) = -\left[\frac{Z_f(p)}{Z_1(p)} V_1(p) + \frac{Z_f(p)}{Z_2(p)} V_2(p) + \ldots \frac{Z_f(p)}{Z_n(p)} V_n(p)\right] \quad \ldots (6)$$

If Z_f, Z_1, Z_2, Z_n correspond to resistance values R_f, R_1, R_2, R_n respectively

Then

$$V_o(p) = -\left[\frac{R_f}{R_1} \cdot V_1(p) + \frac{R_f}{R_2} \cdot V_2(p) + \ldots \frac{R_f}{R_n} \cdot V_n(p)\right]$$
$$= -\left[A_1V_1(p) + A_2V_2(p) + \ldots A_nV_n(p)\right] \quad \ldots (7)$$

where $A_1 \ldots A_n$ are constant coefficients, i.e. addition and scaling has been achieved. Subtraction is obtained by adding the reverse sign of the voltages representing the particular variables. Scaling by a constant $-k$ is achieved by putting $Z_f = R_f$ and $Z_i = R_i$.

If $k < 1$ a potentiometer may be used. The effect of finite forward gain, input current and amplifier phase shift may be determined (*10*), but within the operating conditions of the computer these errors are not usually significant. The basic principles of simulation are more fully discussed elsewhere (*8*, *9*, *10*).

The networks for obtaining some typical transfer functions are illustrated in Fig. 4. A survey of available British analogue computers is given in (*11*).

2.3 Simple example of simulation techniques

To illustrate the different techniques consider the simple position feedback control system illustrated in Fig. 5. The reference input R is the voltage obtained from a potentiometer whose spindle is rotated through an angle θ_i. This voltage is applied to input 1 of a differential amplifier, the output of which supplies the field current of the motor. The armature of the latter is fed from an external supply with a high impedance so that the armature current may be assumed constant. A tachometer attached to the motor shaft is used to provide a voltage proportional to motor speed which is fed back to input 2 of the differential amplifier as a damping signal. A gearbox with a reduction ratio n : 1 is mounted on the motor shaft, the output of which drives a potentiometer. The rotor arm of the latter provides a voltage proportional to the angular position θ_o of the output shaft. This voltage is used as the primary feedback signal to input 2 of the differential amplifier. The operation of the system is that the output shaft is rotated through an angle θ_o to provide a voltage in opposition to the voltage obtained from the input potentiometer. In an ideal system with equal voltages across the input and output potentiometers the angle θ_o would correspond with the input angle θ_i.

The first step in the analysis of such a system is to construct a mathematical model. Consider initially a linear model based on the following assumptions.

2.3.1 Linearizing assumptions

Input and output potentiometers are linear with a transfer function K_1 volts per radian (K_1 is a constant). Note that the effect of finite wire diameter of winding is ignored.

Transfer function of amplifier with field winding connected is $V_f/E = K_2$ (constant), where V_f is field voltage and E is the actuating signal.

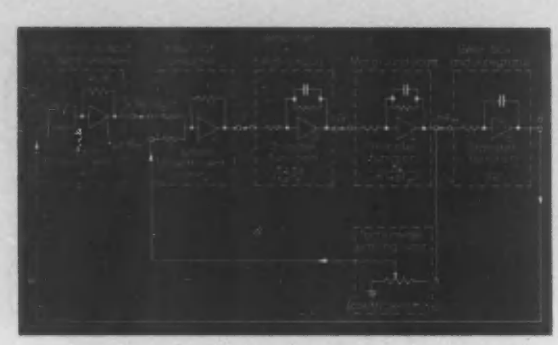


Fig. 8 This computing circuit can also be used to find the performance of the control system, but it differs from the previous one in that it simulates the block transfer functions and so it is unnecessary to develop the differential equations of the system

The field circuit is assumed to have a linear incremental inductance L_f and resistance R_f giving a time-constant $T_f = L/R$.

The field current I_f is given by

$$I_f = \frac{V_f}{R + pL_f} = V_f \cdot \frac{1}{R}\left(\frac{1}{1 + pT_f}\right) = \left(\frac{K_3}{1 + pT_f}\right)V_f \quad \ldots (8)$$

The torque output of the motor is given by

$$F = K_4 I_f \quad \ldots (9)$$

where K_4 is a constant in lb-ft/amp.

The combined polar moment of inertia of motor and load = J slug-ft^2 and combined viscous friction coefficient = f lb-ft/(rad/sec). Static friction is ignored.

$$F = Jp^2\theta_m + fp\theta_m \quad \ldots (10)$$

Hence

$$\frac{p\theta_m}{F} = \frac{1}{(f + Jp)} = \frac{\frac{1}{f}}{1 + pT_m} \quad \ldots (11)$$

where T_m = motor time constant = J/f

The transfer function of tachometer = K_5 (constant)

The gearbox transfer function $\theta_o/\theta_m = 1/n$, i.e. zero backlash is assumed.

A block diagram of a linear mathematical model is shown in Fig. 6(a). An equivalent diagram is illustrated in Fig. 6(b). The development of the differential equations describing the performance of the linear model is given in the appendix.

2.3.2 Differential analyser approach

In this method the differential equations describing the performance of the system are solved.

The differential equation describing the simple system in Fig. 5 is given in the appendix, i.e.

$$\left[T_mT_fp^3 + p^2(T_m + T_f) + p(1 + K_4G) + G\right]\theta_o = G\theta_i \quad \ldots (12)$$

For the purpose of simulation this equation may be rewritten as

$$p^2\theta_o = -\left[(T_m + T_f)p^2\theta_o + (1 + K_4G)p\theta_o + G\theta_o - G\theta_i\right]/T_mT_f \quad \ldots (13)$$

In developing the computing arrangement shown in Fig. 7 for solving this equation, it is assumed that a voltage representing $p^2\theta_o$ appears at the output of the adder 2.*

The output voltage from adding unit 2 is integrated with respect to time in integrators 3, 4 and 5 to give voltages representing $-p^2\theta_o$, $p\theta_o$ and θ_o respectively. The property of the adding device is that its output voltage is equal to minus the sum of its input voltages multiplied by a constant. Thus to make the original assumption valid, the appropriate terms as indicated by the equation, multiplied by the relevant coefficients and taking due account of sign, are connected to the input of adder 2. If a coefficient is less than unity a potential divider or potentiometer may be used. The solution of the equation, i.e. behaviour of θ_o or its derivatives as a function of time in response to a disturbing input voltage representing θ_i, is represented by the voltages appearing at the outputs of the appropriate units. The main disadvantage of this method is that the coefficients of the final equation generally include several parameters of the physical system and it is therefore difficult to investigate the effect of varying one of these parameters.

2.3.3 Transfer function approach

This method differs from the differential equation technique in that the transfer function of each component block is simulated and it is therefore unnecessary to develop the differential equation representing the performance of the system. Referring to Fig. 8, one input to adding unit 1 is a voltage representing $-\theta_i$. It is assumed that a voltage proportional to θ_o is available and this forms the second input to adder 1. The transfer function of the latter is $-K_1$ and thus its output voltage is $K_1(\theta_i - \theta_o)$, which forms one input to adder 2. It is assumed that a voltage representing $-K_2p\theta_o$ is available and this forms the second input to adder 2. The transfer function of the latter is -1, giving an output voltage $-E$, where $E = K_1(\theta_i - \theta_o) - K_2p\theta_o$.

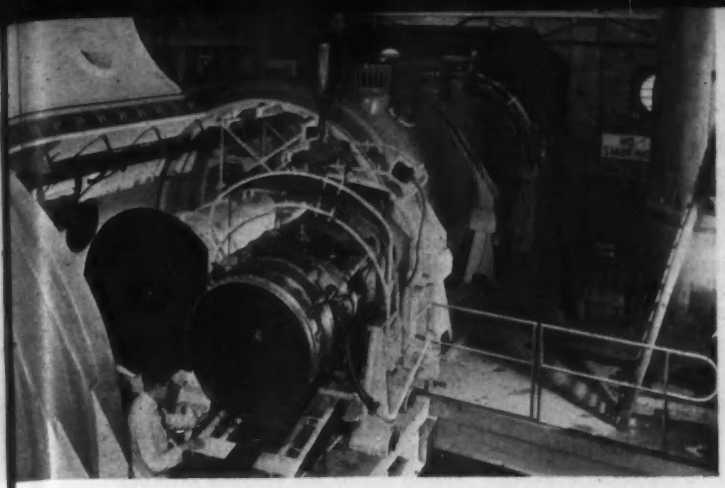
The computing unit 3 represents the combined transfer function of the amplifier and motor field circuit and thus its output voltage represents I_f.

The combined transfer function of the motor armature and load is represented in computer unit 4, which gives an output voltage representing $-p\theta_m$. The latter voltage is integrated in computing unit 5 to give an output voltage representing θ_o. This voltage is fed back to form one input of adder 1. The voltage $-p\theta_m$ is connected to a potentiometer having a transfer function K_2 and the output voltage from this potentiometer fed back to one input of adder 2. In this way the original assumptions are fulfilled and the simulator will now represent as before the performance of the system in response to a disturbing input voltage representing $-\theta_i$.

The main advantage of this technique is that there is a closer relationship between the simulator and the physical system and thus the effect of varying individual parameters is more easily achieved. Another advantage is that if the simulator is operating on a real-time basis, a simulated component may be replaced by an actual component (with appropriate transducers if necessary) to confirm its operation. In this way the simulated components may be replaced in stages by their physical counterparts, as they become available, thus giving a more realistic simulator.

* In a practical set-up, amplitude scale factors are used to ensure that maximum value of a voltage representing a particular variable is within the linear range of the computing unit. Thus if $V_\theta = A_\theta\theta$ where θ is an angle expressed in radians, then V_θ is the output voltage of the computing unit representing this angle and A_θ is the amplitude scale factor (a positive constant with dimensions volts/rad). To illustrate the basic principles of the various techniques in a simplified manner, amplitude scale factors are not included in the above discussion.

to be continued



CONTROL IN ACTION

Speeds of 1800 m.p.h. at heights up to 70 000 ft can be simulated

High Altitude Test Plant

THE FIRST PRIVATELY-OWNED ESTABLISHMENT of its type outside the US, the Rolls-Royce high altitude test plant at Derby, which was opened last month (*News Round-up*), is a very large affair. Some figures are: cost £5·8 million, size 11 acres, power consumption 60 MW. It will enable either turbo-jet or turbo-prop engines to be continuously tested under altitude conditions up to 70 000 ft and up to two and a half times the speed of sound; no longer will flying test-beds be the only means of checking engine performance. There are two engine test cells in the plant, so arranged that an engine can be prepared in one whilst testing is in progress in the other, and a compressor test house, where compressed air from the main plant installation is used to drive a 15 000 horse-power turbine, which in turn drives aero engine compressors on test. The air circuits have been designed so that this rig and either of the main engine test cells can be used at the same time.

Intake, ambient conditions variable

In the main air treatment building air is drawn through electrostatic filters by an input compressor and delivered at 55 psia and 190 deg C. This can be cooled to 8 deg C and dried, and sent direct to one of the engine test cells through a pressure control valve, or to the compressor test rig, or diverted through an expansion turbine to give temperatures down to − 100 deg C. If temperatures above 8 deg C are required, the 190 deg C air is mixed with the air from the former. An engine in one of the test cells can thus be supplied with air at any pressure from 1 to 55 psia and at any temperature between − 90 and + 190 deg C, which will cover intake conditions for any altitude and forward speed envisaged during the next few years. A by-pass circuit common to both cells is included so that control can be exercised during engine accelerations.

Before entering the cell proper the air is fed to a plenum chamber, which contains air straighteners, gauze debris screen, and pressure and temperature measuring instruments. It is separated from the cell by a bulkhead through which is inserted a calibrated air meter connected direct to the engine. During tests this is mounted on a floating cradle connected to a weighing machine for thrust measurement. To get an engine into the cell it is mounted on a dolly which is a transportable part of the cradle and carries battery plates for manometer and electrical connexions. The connecting of the engine tappings to these battery plates is carried out in a preparation room and the engine, mounted on its dolly, is then moved to the cell compartment. Here the assembly is bolted to the floating cradle and the battery plate is connected to the permanent cell instrument lines.

While air is supplied at a desired temperature and pressure to the engine intake, the rest of the engine, including the exhaust or propelling nozzle, is subjected to the pressure corresponding to the selected altitude, down to 0·5 psia. This is controlled by a multi-vane butterfly valve in the exhaust ductwork. The exhaust, which may be at temperatures as high as 1730 deg C, passes through a water cooled tube protruding into the cell, and then out through the exhaust ducting. After going through a primary cooler, the butterfly control valve, and a secondary cooler, it has been reduced to below 70 deg C and is acceptable to the five 22 000 h.p. compressors in an exhauster building. These establish the low pressure conditions in the test cells. They are axial flow machines run at standard speed and subject to a surge condition if excessive pressure ratio is demanded. The critical value of this ratio is a characteristic of the machine, and is affected by the suction pressure, the moisture content and the temperature of the incoming gas.

Auto-controls protect compressors

Control is achieved by means of a hydraulically operated by-pass valve between the suction and the delivery of each machine. In normal operation this is closed but should changing conditions demand a pressure ratio from the exhaust compressors in excess of the critical value, the valve is opened by a pneumatic controller developed by Foxboro-Yoxall. This measures the pressure ratio, compares it with a preset maximum and opens the by-pass valve to protect the compressor if necessary. It is capable of operation between pressures of 0·25 and 60 psia with an

In the main control room the air circuit to suit a required test is set up by inserting templates into the plate desk and lines in use are automatically shown on the mimic diagram

accuracy overall of about 1 pc throughout this range. The control system uses standard pneumatic components, while the set point is adjusted using a computer system correcting for moisture, temperature, pressure and the manually selected value of pressure ratio. Apart from this duty of control, transmitted values of the pressure ratio and limiting pressure ratio are transmitted to the main exhauster control room and remote manual provision is made for adjusting a water spray to the hot gas from the test cells. This is measured by means of a magnetic flowmeter.

The plant's air circuit is controlled from three places—the main control room, engine test control and compressor test control room. In the main control room, the main air circuit to suit the test required is set up, the main compressor sets started and all auxiliaries such as refrigerators, driers, hydraulic pumps and electrostatic filters are started and supervised. Air circuits are selected by the introduction of the appropriate template into a plate desk and a mimic diagram gives a visual indication of lines in use and valve functions. The engine test control room accommodates the engine testing staff and an assistant controller, working together as a team. The former run the engine under test and the latter provides air to the engine at the temperatures and pressures required by the engine test schedule. He can operate only after a permissive switch has been turned by the controller. Complete instrumentation for engine testing is housed in this section, records being obtained photographically. In adjacent rooms, instrument service and electronic recording are provided.

Air conditions held automatically

Ductwork in the exhauster building is so arranged that three of the compressors can be used for an altitude test in one of the cells while the other two provide air power for the compressor test rig near the air treatment building. In addition a pipeline has been laid to a combustion laboratory on a neighbouring site. Interconnexions of the air circuit are achieved by valves of various types. The isolating valves are, in almost every case, electrically operated from the main control room by push button. Where rapid movement is required, hydraulic rams are used instead of electric motors; these are also operated from the main control room by push button. The valves controlling temperatures and pressures in the circuit and the correct functioning of the compressors are all hydraulically powered and, when subject to automatic working, are actuated via magnetic amplifiers operating from signals received from pressure and temperature sensing points. The magnetic amplifiers compare these signals against manually set valves, any out of balance causing movement of the main valve until the error is cancelled. Thus, pressures and temperatures are held automatically, the desired settings having been previously set by the assistant controller. The automatic control is taken a step farther on another desk, where the desired settings can be varied to a programme, enabling an engine under test to be subjected to all the variations met in a complete flight plan.

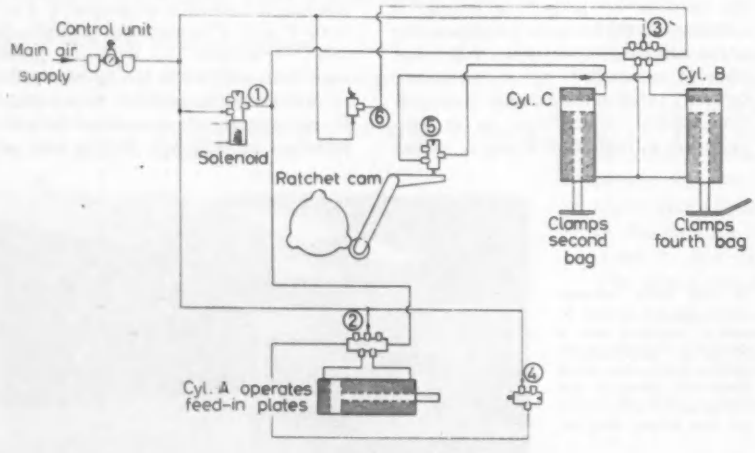
Manual operation of all the control valves can be carried out by switches on both the assistant controller's and controller's desks, and these are being used while the automatic controls are gradually brought into service. Over 200 hours of engine testing has already been carried out during the commissioning of the plant, and it is hoped to achieve testing at the rate of 2000 hours a year within a short time.

High Speed Sugar Packaging

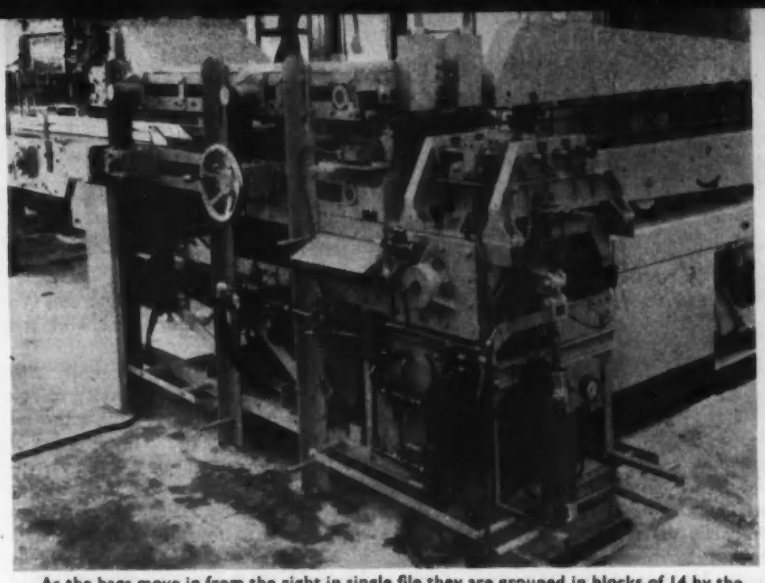
Pneumatic controls help at Tate & Lyle's

A SUGAR PACKAGING MACHINE WHICH makes extensive use of pneumatic controls to increase throughput has now been in operation for several weeks at Tate & Lyle's Liverpool refinery. Manufactured by Brecknell, Dolman & Rogers Ltd, it includes a *Titeseal* unit, a dryer, and a collator. The first unit weighs the sugar, feeds it into bags, and then seals the bags after settling the sugar by controlled vibration. From this point the bags are transferred by moving belt into the next unit, for the drying of the glued flaps, and fed to the collating section, where they are arranged for entry into a parcelling machine. Unlike previous Brecknell, Dolman & Rogers' equipment the new machine employs pneumatic valves and cylinders—made by Maxam Power Ltd—to provide automatic operation of the feed in to the drying and collator sections and speeds of up to 150 bags a minute have been achieved.

Fig. 1 The air circuit operates valves and cylinders to move the bags into the drier at up to 150 a minute



The drier feed-in system consists of six valves, three cylinders and a ratchet cam which operate pusher plates and clamps on the single file of sugar bags and send them forward in groups of fourteen into the drier (Fig. 2). Air for the circuit is delivered through a control unit where it is filtered, lubricated and kept at a constant pressure. When the bags have entered the drier in single file and reached the limit of their travel the leading bag trips a switch which



As the bags move in from the right in single file they are grouped in blocks of 14 by the pneumatic cylinders C and B (top centre) and A (foreground), and sent on to the drier

momentarily energizes the solenoid of valve 1 (Fig. 1) and releases air to set the other valves in operation. While one valve 2 acts to pass air to the cylinder A controlling the three feed-in pusher plates, another 3 allows air to operate the cylinder B which clamps the fourth bag so that the leading three bags are moved off at right angles to the original line of travel.

The valves reset as follows: when the piston rod of cylinder A is fully ex-

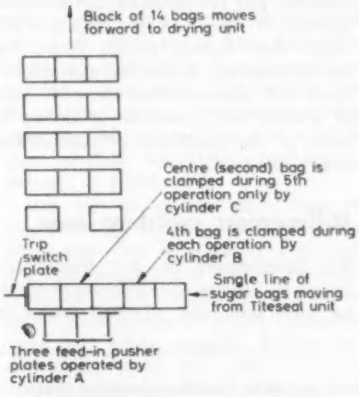

Block of 14 bags moves forward to drying unit
Centre (second) bag is clamped during 5th operation only by cylinder C
4th bag is clamped during each operation by cylinder B
Trip switch plate
Single line of sugar bags moving from Titeseal unit
Three feed-in pusher plates operated by cylinder A

Fig 2 On the fifth stroke of the feed-in pusher the second bag is clamped so that only two move forward

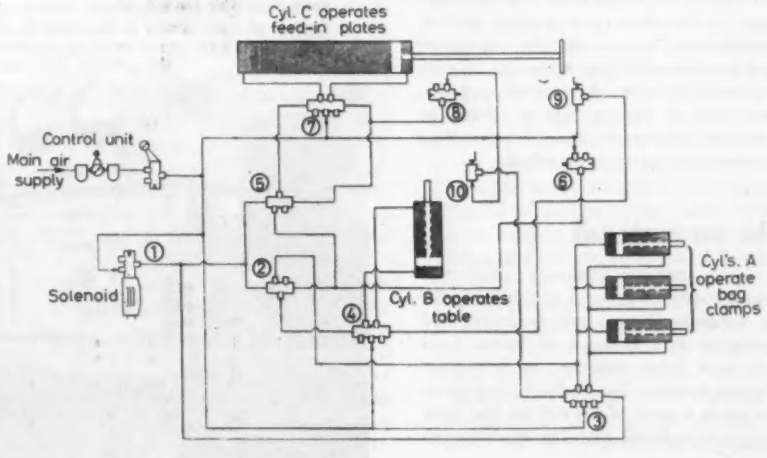
tended valve 4 is depressed, which passes air to the left hand end of valve 2. This resets and passes air to the right hand end of cylinder A, retracting the piston rod and releasing valve 4 which resets. But meanwhile the piston of cylinder A, in extending to move the first three bags into the drier, has operated valve 6 by a one way trip. This leads to the unclamping of the fourth bag so that the line of bags can move forward again (air passes to the right hand end of valve 3, which resets and passes air to the bottom of the cylinder B, clamping the fourth bag).

This sequence is repeated three more times, making four identical operations and directing in all four rows of three bags into the drier. On the fifth stroke of the feed-in pusher (cylinder A) a ratchet cam operates valve 5 (air was passed to the inlet part of this valve by the valve 1 at the beginning of the action). Air reaches the top of cylinder C and the piston rod extends to clamp the centre (second) bag. Thus only two bags (one and three) are pushed off, bringing the total to fourteen in the five operations. While on its way through the drier the centre row of four bags is turned through ninety degrees so that the narrower side of the packages leads. As a result the centre row is equal in length to the two outer rows of five bags, each of which have their longer sides leading and the fourteen bags form a rectangle.

The controls have proved very successful in use—'first class,' Tate & Lyle told CONTROL—and much better than the mechanized methods previously used. Brecknell, Dolman & Rogers plan to fit them to all their future sugar packing machines.

The original installation included a parcelling unit, but as a result of mechanical teething troubles it is not in use at the moment. No difficulty was experienced with the feed-in controls, however, which again consist of valves and pneumatic cylinders. A row of six cylinders A operate clamps against the oncoming three rows of bags after a group of 14 has arrived in the unit. The sequence is started by trip plates which operate a microswitch: a pulse passes to energize the solenoid of valve 1 (Fig. 3) and valves 2, 3, 4, 5, 6 and 7 are brought into action to operate the clamping cylinder and another cylinder B which operates a linkage to shift the table and remove the pressure from the oncoming line of bags. When the table is in position valve 6 is depressed and valves 2, 7, 5, actuated. The piston rod of cylinder C retracts, and in doing so pulls out a feed-in plate, moving the 14 bags into the parcelling unit. When this has completed its stroke valve 8 is operated and air passes to valves 5 and 7. Valve 7 resets and causes the piston rod of cylinder C to extend and return the feed-in plate to its former position. A one way trip valve 9 is operated and valve 4 passes air to the bottom of cylinder B to return the table. Another one way trip valve 10 causes cylinder A to release the bag clamps, allowing the bags on the collator conveyor to feed forward ready for another cycle of operations. Fast parcelling machines are notoriously difficult jobs, but the manufacturers think they can get over the initial troubles on the mechanical side and set new records in handling speeds.

Fig. 3 Clamps and a table mechanism are brought into action by the valves and cylinders when the solenoid of valve 1 is energized, and a feed-in pusher takes 14 bags into the parcelling machine



NEWS ROUND-UP

——COMPUTERS——

Tackling that 95 pc

Recent developments in the electronic control of machine tools could make the impact on the capital-goods industries which special purpose machine tools have made on mass production techniques—and it seems probable that Britain's future lies in the production of specialized capital equipment. This view was advanced by D. T. N. Williamson of Ferranti's in opening a discussion at an IEE Measurement and Control Section meeting recently. 'The methods used for this type of equipment, in which relatively small quantities are involved,' he went on, 'have so far been developed very little by comparison with mass-production methods.' The problem of batch production is primarily one of information handling and data processing. In a factory devoted to the manufacture of small quantities of intricate electromechanical equipment of advanced design, for instance, which mainly involves the manufacture of machined metal parts, less than 5 pc of the total labour is expended in the actual cutting of the parts. The rest is involved in information handling and data processing. 'It is clear, therefore,' he stressed, 'that there are vast potential savings if these processes could be made more automatic.' The development of electronic and electrohydraulic copy turning lathes after 1940 was an attempt to bridge the gap between the skilled turner at one extreme and the fully-automatic cam-controlled lathe at the other. Such methods made possible the economical manufacture of small batches of turned components, the control data being produced as a template, but they did nothing to solve the major data-handling problems involved in the production of the template. 'The introduction of the idea of numerical control, whereby machine tools and other equipment can be controlled from numerical data by means of computers, has opened up a vast new field, at the far side of which the complete solution to these data-handling problems can be dimly perceived.'

This one might talk

A large analogue computer which will simulate nervous systems and may be able to recognize shapes such as letters and numerals—and perhaps even human faces—is now being designed at University College, London. The Nuffield Foundation has made a grant of £34 000 for this work and it is expected that the machine will be built by the end of 1960. The Foundation's annual report, published on 16th October, says that the possibilities of the new computer should be considerable. It will be on a much larger scale than the small 30-unit machine developed by Dr W. K. Taylor. This was able to utter a sound of recognition when a shape which resembled one it had previously learned to classify was put before its electronic eye. It is probable, the report continues, that the process by which the brain recognizes shapes has four stages: (1) analysis of the shape presented into a form suitable for storage (2) storage of the record of the shape (3) using this record to control the response when test shapes are presented, and (4) the generation of motor patterns appropriate to the stimuli. A digital computer is too slow for this kind of work. It would take perhaps fifteen minutes to answer a question which the nervous system of an animal answers in a fraction of a second. The new computer should deal with the question 'just as fast', states the report.

Analogue networks will be trained

It is to consist of about 4000 identical units, which may be called N units. Each will be an electronic analogue of a single neuron and its synaptic terminals. It is believed that in an animal information is stored at the synapses between neurons, and that the receipt of nerve impulses changes the transmission power of the synapse. The N units will be constructed to perform in the same way and thus give the computer a memory. To investigate the connectivity patterns of nature, this will be arranged so that any network of up to 4000 cells of the machine will deal with messages for which an animal uses a much larger system, for the cells in a machine, unlike those in nature, work at a high level of efficiency.

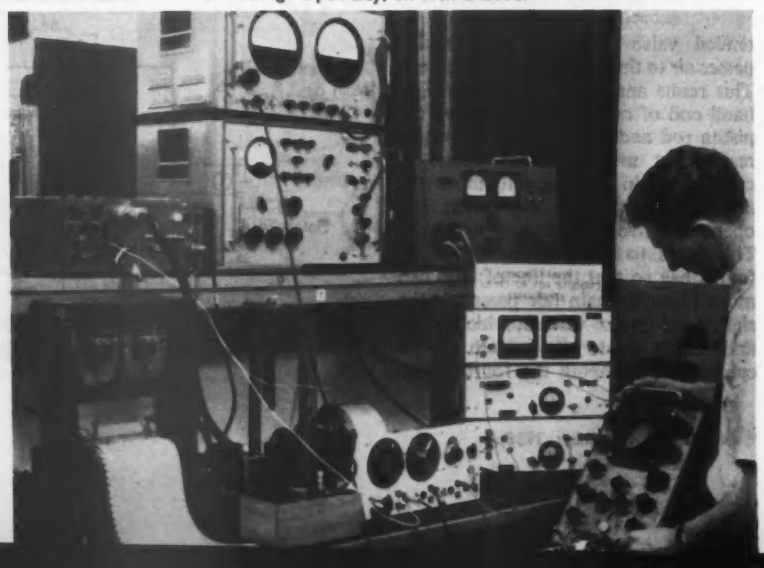
Dr Taylor's original computer, tiny though it was, could solve network problems that were too complex to programme on a digital computer. In the investigation of the theory of how an animal stores representations of past events, the analogue networks will be trained to recognize shapes held in front of the computer's model eye. As each different shape is presented to the eye a different sound will be made in the machine's model ear. If the training is effective, the computer will be able to emit the appropriate sound when a shape is brought into its field of vision. Experiments with distorted versions of the learned shape will give important information about the properties of the networks, and the machine's responses can be compared with those of animals similarly trained and faced with the same distortions. The eye of the new computer will also be able to deal with theories of colour vision.

It should be possible, according to the report, to simulate the learning of the alphabet and the numerals and a limited number of more complex shapes, which might even include human faces. The output stage will control the movement of levers that could simulate the movements of animals, the production of writing by man, or the generation of recognizable speech sounds.

Millimicrosec switching soon

The development of low temperature devices for storage and switching is one of the most promising of recent trends in

FIRST STEPS IN SERVOS This equipment is used to introduce students at the College of Aeronautics to the elements of servomechanisms and analogue simulation. It was one of the many working exhibits and models which were on display during the College Open Day, on 10th October



computer techniques and machines are now being designed to carry out about a million arithmetical operations a second, said J. K. Webb of Standard Telecommunications Laboratories recently. Giving an address to the Measurement and Control Section of the IEE which outlined the scope of the Section he pointed out that one session of the forthcoming specialist discussion meetings will be devoted to the use of these devices. Since 1940, when the idea of applying electronics to computers was first mooted, he went on, practically every effect known to science which can be said to possess a 'memory' has been explored, even including such unlikely ones as thixotropy, and more esoteric ones such as spin echoes based on nuclear induction. The two most important questions to consider in assessing the merits of any memory system are access time (the time required to transfer the information from the memory unit through the associated circuitry to the point of need), and economic factors.

Superconducting elements the best?

Typical of the devices which have so far come out on top are magnetic tape, magnetic drums, magnetic elements and now, the latest, superconducting elements, he said. Access times were of the order of: magnetic tape 10 sec, magnetic drum 10^{-2} sec, magnetic elements 10^{-5} sec and low temperature devices 10^{-8} sec. They can all store digits by virtue of the remanent magnetism which results from the application of a magnetizing force greater than a certain critical value. The relatively low cost of the magnetic drum, combined with large capacity and an access time which is short enough for many applications, explains its popularity.

One way of constructing a store of magnetic elements is to use tiny ferrite cores which must first be individually checked and then threaded with appropriate windings. The matrix, comprising a number of such cores assembled to form a co-ordinate array, is a typical example. At least two co-ordinate wires, an inhibit wire and usually a fourth 'reading' wire must be threaded through each core, and, with the desirability of making the cores as small as possible, this is not an operation which lends itself too easily to large-scale manufacture, taking a megabit store as a basis of reference (which is the size necessary to store the information of a small 30 000-word novel). Alternative methods include forming the elements by means of ferrite wafers perforated with holes, the ferrite in the immediate vicinity of each hole serving the same function as a discrete core, or else the use of deposited thin films of magnetic alloy. The capital cost of such stores is at present about 20 times that of magnetic drums of the same capacity, so that they tend to be limited to small buffer stores used in conjunction with the latter.

A recent and novel variant on storage in magnetic elements is the Bell Laboratories' Twistor, which, by replacing ferrite cores with straight magnetic wires, would seem to facilitate large-scale production. The device depends upon a curious phenomenon, that, if a magnetic wire is twisted, magnetization will prefer to be along a helical rather than a longitudinal path. 'Its development will be awaited with interest,' said Mr Webb. There are other variants, including 'window'-type elements designed to increase the switching speed, but these are more elaborate as they have to be provided with supplementary windings to provide bias.

Cost could be high

Anyone who undertakes such development work must always be distracted by the necessity of constantly looking over his shoulder to see how likely he is to be overtaken by some alternative scheme. For a time there was competition from cathode-ray tubes and ferroelectrics, but at present they do not appear to be in the running, although some fresh development may completely change the situation. The latest challenge, however, has come from a rather unexpected source—low-temperature devices. The phenomenon of superconductivity in various metals at temperatures below about 10 deg K was discovered in 1911, but it never assumed engineering significance until helium liquefiers or 'cryostats' became commercially available in 1954, and an account appeared in 1956 of a superconductive computer component called the Cryotron. This is a new circuit-element having power gain and current gain which can be used in flip-flop circuits, gates, counters and other computer circuits. In 1957 a memory cell based on flux trapped in superconductors by the application of a magnetic force above a certain critical value pointed the way to the design of a large memory having a cycle time of only 10^{-6} sec. This very fast switching speed is of great interest to computer designers. Machines are now being designed to perform about a million arithmetical operations per second, and arithmetical circuits and stores act as each other's pacemakers. 'It is too early even to hazard a guess at the capital and operating cost of such a store,' he thought.

NEW TV STUDIO AT COLOGNE Combinations of lights selected by the keys at the top of the console are stored and can be brought back at any time by a series of 14 push buttons

TELEVISION

UK lighting controls for Cologne

The first specially built German television studio was recently completed at Cologne. Original plans called for all-German manufacture, which was hardly surprising in view of the efficient electronics industry there; but following a visit by the Technical Director to BBC studios in England only a few months before completion date, it was decided to switch to British equipment for the lighting and lighting control apparatus. It is reported that he was impressed by recent developments in this country and realized that television imposes its own problems which would not be successfully overcome by the conventional film studio apparatus he had in mind. An order was placed with a British firm—the Strand Electric and Engineering Co—and the whole equipment was completed and installed in twelve weeks. 'Probably the most remarkable job we have yet undertaken', director F. B. Bentham told CONTROL.

BBC system modified

The studio is medium sized, of roughly 3500 sq ft, and the rigging and suspension apparatus, which was made by Rae Stage Equipment Ltd, uses 8 ft motorized bars rather as in the Riverside Studios of the BBC. There are 40 of these bars in four rows of ten down the studio, and each has four 2 kW outlet sockets. Power is fed in through a lattice of folding tubes which renders special cabling, such as the self-coiling cabling of Riverside, unnecessary. It is difficult to say yet which is the better method, but both provide interesting solutions of the problem of how to feed a bar which travels over 30 ft without any loose flex. Each winch is self-contained with its motor, and is controlled from a central panel. They can be lowered singly or in groups so that one button will control a lighting arrangement

involving several suspension bars. The circuits on the bars are taken to a dimmer room where the actual current control equipment is housed; the 62 dimmers are auto-transformers driven through electro-mechanical clutches from a single motor-driven shaft. This system has been used for a number of years by the company and a recent improvement is the addition of a polarized relay servo to give greater accuracy.

The advantage of the electro-mechanical system of dimmer control is its inherent inertia, and the control desk at Cologne is designed to make full use of this by providing the operator with facilities for immediately selecting the circuits which have to *change*, working on them and then, so to speak, returning them in that state to rest until needed once more. Basically, the console has an organ type selector switch stop-key to every control channel and these are used to select the circuits required; they are linked also to a memory storage system in the console which enables combinations of these to be instantly memorized and brought back at any time by a series of 14 push-buttons. Two duplicate sets of dimmer levers are provided on the console and either set can be connected to the dimmer servo to make the dimmer take up the appropriate position. The network is not connected as a whole: only those circuits which have been selected at the stop-key are so connected by the master button. Fourteen variable group selections can be made in respect of the two duplicate sets of levers and each of 14 groups can have two levels of intensity preset in advance, the preset levels being quite independent of any level which the dimmer is holding at that moment.

— IRON AND STEEL —

New device warns crane drivers

A device of the echo sounding type is being tried out at Richard Thomas and Baldwin's Redbourn steelworks to reduce the danger of collision between travelling cranes working on the same tracks. This problem has been troubling the industry for many years: cranes and large objects are continually moving up and down a big shop, but drivers have to concentrate on their loads and the signals of their slingers and have no time to watch neighbouring cranes. The warning system, developed by British Thomson-Houston, uses an oscillator mounted on one crane to generate short pulses at regular intervals. These are emitted as 11 kc/s sound waves which are turned back by a special trihedral reflector fitted on the neighbouring crane. The echo is picked up by a microphone mounted alongside the sound source, amplified, and fed to relays. The signal can then be used to operate audible or visual alarms in the driver's cab, or to initiate automatic braking of the crane. Time taken for a return echo to operate the protective system is 2 millisecs per foot, and selective circuits are designed to respond only to the genuine echo. The reflectors are portable and could be placed anywhere in the path of the sonic beam to prevent overrunning of end stops or danger to men carrying out maintenance work on another crane. Maximum operating distance achieved so far is 60 ft.

LOOK, NO HANDS! A pilot sits back while his plane is landed by the automatic controls developed by the Blind Landing Experimental Unit

—— AIRCRAFT ——

BLEU controls land 2000 planes

Completely automatic landings may soon be a regular feature of airline practice following research carried out by the Royal Aircraft Establishment's Blind Landing Experimental Unit at Bedford. A system has been developed that controls the aircraft during the complete landing process and enables touchdowns to be made without the pilot handling the controls or seeing the ground. Over 2000 successful landings have been made in both propellor and jet aircraft and several demonstrations were given to representatives of British and American airlines on 16th October. As soon as the system has been engineered to meet safety standards and internationally accepted it can go into normal use by airlines. At present civil aircraft can approach on instruments or stay locked to a radio beam only down to a height of about 150 ft; after this the pilot must take over and if visibility is too poor for him to see the runway—as often happens—the attempt to land must be abandoned.

In the BLEU system standard automatic practice using a modified Smith SEP2 autopilot and a Pye Instrument Landing System is employed down to 300 ft. At this level azimuth guidance to the autopilot is automatically switched to a Magnetic Leader Cable System. This was developed by Murphy Radio and consists, on the ground, of two cables situated about 250 ft on either side of the runway centreline and extending from about 5000 ft beyond the threshold in the undershoot area to as far along the runway as azimuth guidance is required during the ground roll. Each cable is fed from an alternator with a current at a different frequency, the current being kept constant by an electronic control circuit. The magnetic fields from these cables are detected in the aircraft by a small rotating loop, and their value is compared in a simple receiver. This allows position relative to the runway centreline to be determined to better than 5 ft.

Radio altimeter takes over at 150 ft

At a height of about 150 ft, the ILS glide path signal may become unreliable on some installations, and so at this height the signal is switched out automatically by the radio altimeter, and the aircraft maintains the average attitude it has adopted during its approach from circuit height. This condition is maintained only for a brief period, until a height of about 60 ft, when the radio altimeter is used for the final flare-out. It is of the frequency modulated type, a variant of the STR30 modified by Standard Telephones to a BLEU specification. It provides not only a very accurate measurement of height above ground, but also can detect a change of height of not more than 2 ft and can therefore produce a signal accurately proportional to rate of change of height. These properties are used from below about 60 ft, to control pitch attitude so as to make the rate of descent proportional to height. This gives a very smooth flare-out and is used right down to touchdown.

At about 20 ft, any drift due to cross-

wind is rectified automatically. Leader Cable guidance is disconnected, the wings are levelled, and rudder is applied to change the aircraft heading to that of the runway (preset on the gyro compass by the pilot at the start of the automatic landing). When the aircraft touches down, the pilot disconnects the automatic control by pressing a button on the control column, steers the aircraft himself and brings it to a halt using information from the Magnetic Leader Cable presented on the instruments. An important feature of the system is that during all phases of the automatic landing, monitoring signals are displayed on the normal flight instruments which form part of the Smith's Flight System. The only additional instrument is a sequence indicator which displays the successive phases of the landing.

The final component is the Automatic Speed Control. This controls the throttles automatically so as to maintain a constant preset speed during the approach until flare-out, when the throttles are closed to safe idling speed in a prescribed manner. Assuming an autopilot will be carried in any case, the system requires the following additional equipment in the aircraft:—Control box and sequence indicator, Automatic Speed Control, Leader Cable receiver and aerial, low level Radio Altimeter and aerial, weighing in all about 100 lb.

UK sets up rocket data centre

A third World Data Centre for rockets and satellites is now operating at the Radio Research station of the DSIR at Ditton Park, near Slough, Bucks. Up to now there have been only two centres—at Moscow and Washington—which were set up under the International Geographical Year arrangements, and it was agreed at the recent Moscow meeting of the Special Committee to accept a British offer of a third.

Many of the satellite experiments are concerned with studies of the ionosphere—one way of gaining information about it is by investigating the travel of radio waves from satellite transmitters, and work of this kind has been in progress at the Radio Research station.

——CHEMICALS——

Glaxo to use an Emidec 1100

Home sales orders and related accounting at Glaxo Laboratories are to be carried out in future by an EMI Emidec 1100 computer. It will replace the clerks who handle the orders for several thousand items a day of the 450 different packs supplied by the company. Other tasks will include managerial and sales statistical work, together with stock control of the three warehouses which serve the home market. Export orders, because of their variety, are treated as special production jobs but works scheduling is becoming more and more complex as the range of products increases. It is hoped to use the computer eventually for processing these orders as well, and for looking after material stock control, work scheduling, progress control and payroll.

EMI have recently organized a series of three-week training courses at Hayes for programmers from customers' staffs and for other executives interested in the Emidec 1100. The next starts on 12th January and will take in tours of several EMI factories, including, amongst others, those where computers and magnetic tapes are manufactured.

——RAILWAYS——

Watford goes automatic

Following the installation of programme machines for automatic signalling at Kennington and Camden Town (*Control in Action*, August) London Transport has now completed a similar set-up on a surface station. The signal box at Watford Metropolitan line station has been taken out of service and mechanical signalling replaced by automatic controls supervised from Rickmansworth, three miles away.

All signals and points are controlled from shafts in a 36-shaft interlocking machine housed in a new fireproof building between the running lines at the south end of the station. The machine is provided with mechanical interlocking and with contacts for the control of the signalling circuits. Each shaft is equipped with air cylinders and electro-magnets which will be energized by the remote control circuits—programme machines, automatic reversal operation, or by push buttons from Rickmansworth. Sealed relays of the telephone type are used for the non-safety circuits operating the interlocking machine shafts.

Each tongue is locked separately by the electro-pneumatically operated mechanism in the casting on the right

London Transport has been toying for some time with the idea of going over to the chairlock type of point control employed by the French National Railways. An experimental installation at Earls Court station has worked well and the new signalling apparatus at Watford is equipped entirely with this system. Modifications of the French method include the provision of an electro-pneumatically operated ground tracklock which is provided on facing points over which passenger trains operate, and a detector which separately detects each switch and the ground tracklock in the locked position.

French idea borrowed

This is the first time that the production model of this modified chairlock has been used, and it is applied to 12 pairs of points at Watford. Its essential feature is that the closed tongue of the points is held firmly clutched to the stock rail when locked. The actual locking mechanism is enclosed in a casting forming part of the chair which supports the end of the switch tongue, so that there is a separate lock for each tongue. This is in contrast to the usual method employed in this country, which consists of a plunger acting on the stretcher bar.

The drive rod of the layout is connected

JUPITER IN THE CLASSROOM Made by US Rocketdyne, this vertical arrangement of actual components, scaled down propellant tanks, propellant ducting and thrust chamber allows an entire Jupiter missile propulsion system to be simulated for training US Air Force students at Redstone Arsenal, Alabama. Leakage, blocked lines, interrupted firing circuits and electrically malfunctioned control valves can all be 'placed' in the trainer and must be corrected by the student before the electrical and pneumatic system will function correctly

CONTROLLING CAR PAINTING The operation of two painting lines with an output of 52 bodies an hour is controlled from this panel at Morris Motors

to two switch locking arms that pivot at each switch and are in the form of cranks, one arm of which is connected to the electro-pneumatic operating cylinder. The second arm is provided with locking faces which engage with corresponding faces in the lock box chair castings. The switch locking arm cannot move until the ground tracklock is lifted, which in turn is locked by the occupancy of the protecting track circuits. The detector has been redesigned and the detection contacts can only be closed to allow the signal circuits to be completed when both switches are in the correct position and held in that position by the ground tracklocks. The lines are continuously track circuited by means of single rail condenser feed track circuits. Rail circuits of the 10KC type have been provided to detect that trains passing over facing points have completed their route and that the back-locking requirements have been satisfied.

CARS

Auto-control at Cowley

The British Motor Corporation's new £3 million body painting plant at Cowley makes the most of modern ideas on layout and instrumentation. 180 machines ranging from 1 to 50 h.p. are employed to drive supply and extract fans, water pumps, conveyors, recirculating fans, etc., and the whole of the equipment is controlled from a main board in the central control room. Total designed output of the plant is 52 bodies an hour from two identical lines, and it will shortly go into full operation with its own *Rotodip* installation. In this the car bodies are rotated on a spit through baths of anti-corrosion primer; it will be equipped with fully automatic loading and unloading gear which will also insert the spits at the loading end, remove them at the unloading end and return them to the loading end. After various drying and cooling operations the bodies on the conveyor lines pass through the paint spray booths, which are equipped with Carrier-Schweitzer automatic painting machines. The painting process is started when a body enters the booth and breaks a beam to a photo-electric cell and cams are employed to make the spray guns follow the contour of the body; about 85 pc of the surface can be painted in this way.

The conveyor belts are driven by 3 h.p. Crompton Parkinson motors via Heenan & Froude magnetic couplings and each drive is equipped with a tachogenerator. The motors are controlled from fifteen cubicles located in strategic positions about the plant. Fault indication for every machine is given in the cubicles and the general overall fault indication shows up a mimic diagram in the main control room. The whole plant is started and stopped from here and the 20 King conveyors are synchronized from the control desk. Body positions on any two associated conveyors are maintained using Muirhead Magslip synchronizing generators when the conveyor system speed is varied. Controls generally are carried out by uniselectors working Post Office type relays, which in turn actuate 10 amp relays for the motor starters. All the control equipment was designed by Lee Beesley & Co in conjunction with the main plant contractors, the Carrier Engineering Company, and plug-in construction is extensively employed for the timing relays, electronic timers, etc.

IN BRIEF

● **Roads** At the Public Works Exhibition, Olympia, Gilbarco Ltd are showing, for the first time in this country, an automatic remote 'Binder metering and control unit'. This enables an operator to preset the quantity of binder required; when the start button is depressed the preset quantity is automatically fed direct into the mixer. At the end of the delivery valves are automatically actuated and the bitumen or tar continues to circulate in the ring main until the start button is depressed again.

● **Atomic energy** Following the news that a Pace analogue computer is to be used at Harwell (*News Round-up*, last month), the European Division of Electronic Associates Inc announces the sale of its twentieth since July '57, this time to the GEC Atomic Energy Division.

● **Components** Elliott-Automation announces that its subsidiary company, Associated Automation, has signed agreements with both the Farris Engineering Corporation of New Jersey and the Farris Flexible Valve Corporation. A new company, Farris Engineering Ltd, has been formed to manufacture and sell in the whole of Europe, the British Commonwealth (except Canada) and the Middle East the Farris range of Safety-Relief Valves and Pinch-Type 'Flex Valves.'

● **Instruments** The Solartron Electronic Group is to manufacture the Kintel range of meters, amplifiers etc of the US Control Electronics under selling and manufacturing agreements covering the whole world outside the Americas with the exception of Sweden.

● **International** The British Conference on Automation and Computation has now joined the International Federation of Automatic Control. Other new members are Belgium, Holland, Hungary and Turkey.

FIRST CORDLESS SWITCHBOARD At the Canadian Pacific Railways' offices in Trafalgar Square, London, an official makes the first call through the new pushbutton switchboard which will replace the old equipment on the right. Working by means of P.O. relays it controls a private automatic branch exchange manufactured by the Automatic Telephone and Electric Co

MANUFACTURER	DESCRIPTION	CLOCK FREQUENCY	NUMBER BASE	WORD LENGTH	INSTRUCTION CODE	ARITHMETIC UNIT	STORAGE
ritish Tabulating Machine Co Ltd, The Tick No 137 on reply card	Hollerith type 1202 electronic digital computer	38·4 kc/s	Binary	Basic, 40 binary digits	1+1 Address code, permitting optimum programming. One instruction per word, composed essentially of an operand address, function, next instruction address, and counter for controlling the function	Serial. Add'n, subt'n, mult'n & div'n. Shifting operations within and between the quick access stores. Basic operation time 1·25 msec	(1) 4 quick access stores, each of one word length (2) Magnetic drum with a capacity of 4096 words on 256 tracks, 16 words/track
ritish Tabulating Machine Co Ltd, The Tick No 138 on reply card	Hollerith type 555 electronic calculator	16·8 kc/s	Binary coded decimal	10 decimal digits	3-address (plugged)	Serial parallel	Main storage capacity: 1050 digits (105 words)
ritish Tabulating Machine Co Ltd, The Tick No 139 on reply card	Hollerith type 1400 electronic digital computer	1 Mc/s	Binary coded decimal	11 digits and one word parity digit	3-address type	Serial parallel. Word time 16 μ sec. Execution of one instruction and reading of succeeding instruction are concurrent	(1) High speed cores 100 words, (2) Main storage drum of 11 250 words capacity
Burroughs Adding Machine Co Ltd Tick No 140 on reply card	Burroughs 205	132 kc/s	Binary coded decimal	10 digits +sign	Single address, one instruction per word	Fixed point operation basic, floating point available. Add time 1·0 m/sec QAS (including access time). Product length 20 digits+sign. Divide time 12·7 msec QAS	(1) Quick access storage (QAS). 80 words. Access time 0·85 sec. (2) Main storage (magnetic drum) 4000 words. Block length 20 words (transfer to QAS). (3) External storage by mag. tape, maximum 20 000 000 words
Burroughs Adding Machine Co Ltd Tick No 141 on reply card	Burroughs 220		Binary coded decimal	10 digits +sign	Fixed and floating point operation basic. Add time 185 μ sec (including access time). Multiplying time 2970 μ sec (including access time). Product length 20 digits+sign. Dividing time 3985 μ sec (including access time)		(1) Quick access storage (QAS). 2000–10 000 words (magnetic cores). Access time 10 μ sec (2) External storage by magnetic tape, maximum—48 800 000 words
Burroughs Adding Machine Co Ltd Tick No 142 on reply card	Burroughs E101	78 kc/s	Pulse coded decimal	12 digits +sign	Single address	Add time 50 msec (including access time). Product length 12 digits+sign. Divide time 250 msec (including access time)	(1) Main storage (magnetic drum) 220 words (2) No quick access storage
Elliott-Automation Ltd Tick No 143 on reply card	Elliott 402E computer	333 kc/s	Binary	32 digits	One order per word. 1+1 address. 7 B-line registers	Serial. Add, subtract, multiply, divide, shift, various logical functions and two conditional transfer instructions	Drum 4976 words, together with 16 immediate access single word nickel delay lines
Elliott-Automation Ltd Tick No 144 on reply card	Elliott 402F computer	333 kc/s	Binary	32 digits	One order per word. 1+1 address. 7 B-line registers	Serial. Add, subtract, multiply, divide, shift, various logical functions and two conditional transfer instructions	Drum 4976 words, together with 16 immediate access single word nickel delay lines
Elliott-Automation Ltd Tick No 145 on reply card	Elliott 802 computer	166 kc/s	Binary	33 digits	2 orders per word. Any storage register may be used as B-line modifier	Serial. The 64 different functions include arithmetic, logical and conditional transfer instructions. Overflow indicator on all instructions	1024 word magnetic core store
EMI Electronics Ltd (Computing Div) Tick No 146 on reply card	Emidec 1100 digital computer	112 kc/s	Binary for arithmetic working; sterling, decimal, or alpha-numeric for input and output	36 binary digits	27 two-address instructions	Addition and subtraction take 125 μ sec and multiplication and division 1120 μ sec. (These times include any B-line modifications and three access times to the immediate access store)	(1) A 1024 'word' immediate access store of magnetic cores interlaced to form a matrix provides a range of accumulating registers and also holds the programme currently in use. (2) Drums of 8192 and 16 384 words provide the main internal store. Any reasonable number of drums may be used. (3) High-speed magnetic tape decks with a tape storage capacity exceeding 13 million binary digits or 2½ million alpha-numeric characters and a read/write rate of 20 000 characters/sec
EMI Electronics Ltd (Computing Div) Tick No 147 on reply card	Emidec 2400 data-processing system	1 Mc/s	Both binary and alpha-numeric data are processed, though all arithmetic operations are performed in binary	Binary words—36 bits. Alpha-numeric words—6 characters (36 bits)/unit. Variable word length of up to 15 units per word	Form of two address type. One address covers both the computing store and high speed store and the other only the high speed store. Any position in the high speed store can be used as modifier (B-line). Besides the normal orders a comprehensive set of input and output orders and conversion orders to and from binary are provided. Most instructions are set up and executed in 25–40 μ secs	A fast asynchronous 36 bit parallel adder with automatic carry and error detection. Complex arithmetic operation performed by repeated operation under a high-speed built-in control	(1) Computing store—4096 words of 37 bits using magnetic core storage; cycle time 15 μ sec. (2) High speed store—64 words of 38 bits using diode-capacitor storage; cycle time 4 μ sec. (3) Peripheral storage—magnetic core storage is used in off-line peripheral units and fast start-stop one-inch magnetic tape to integrate the system. Four inch wide magnetic tape is used for bulk storage. Both tapes operate at 20 000 characters/sec
English Electric Co Ltd Tick No 148 on reply card	Deuce Mk I (digital electronic universal computing engine)	1 Mc/s	Binary	32 binary digits	Can be described loosely as a 2+1 address	Serial. Mult'n and div'n times are 2 msec and add'n and sub'n 64 μ sec inclusive of time to obey instruction. All arithmetic operations are fixed point, but floating point routines are available	(1) A high-speed store with a capacity of 4 words. (2) A lower speed magnetic drum storage of 8192 words. (3) Magnetic tape units for auxiliary storage

DIGITAL COMPUTERS

	INPUT	OUTPUT	POWER CONSUMPTION	FLOOR AREA, FT²	APPROXIMATE COST	MAIN APPLIC
, each of one word m with a capacity of s, 16 words/track	80-column card reader, operating at 100 cards/min. 12 binary numbers/card, or up to 64 non-binary digits converted to binary by built-in circuitry	Line printer, operating at 100 lines/min. 80-column card punch, operating at 100 cards/min. 12 binary numbers/card, each of 53 digits (number + drum location + 1 spare digit). 64 non-binary digits/card or line of print. Additional storage for output only up to 64 characters	14 kW	400	£40 000	Commercial
1050 digits (105	Hollerith 80-column punched cards, 100 cards/min	Hollerith gang punch, 100 cards/min	14 kW	300	£25 000	Commercial scientific
0 words, (2) Main words capacity	600 punched cards/min	400 printed lines/min		Up to 1000	£100 000–£150 000	Commercial
(QAS). 80 words. Main storage ords. Block length AS). (3) External aximum 20 000 000	(1) Punched card up to 240 cards/min (2) Paper tape. 540 characters/sec (3) Keyboard available	(1) Punched cards. 100 cards/min/unit (maximum 7 units/system). (2) Paper tape 60 characters/sec. (3) Line printer. 150 lines/min/printer, 120 characters/line (maximum 7/system)	Varies	600 –1200	£225 000 (average commercial system)	General pur
e (QAS). 2000–10 000 . Access time 10 μ sec. magnetic tape, words	(1) Punched cards up to 240 cards/min (2) Paper tape. 1000 characters/sec (3) Keyboard available	(1) Punched cards. 100 cards/min/unit (maximum 7/system). The No. 2 line printer. (2) Paper tape. 60 characters/sec. (3) Line printer. 150 lines/min/printer (120 characters/line, maximum 7/system. The No. 2 line printer can be used instead—900 lines/min, 120 characters/line, 6 lines/in.	Varies with system configuration	600 –1200	£375 000 (average commercial system)	Scientific, co financial
netic drum) 220 words. orage	(1) Punched card. Up to 15 cards/min (2) Paper tape 200 characters/sec (3) Normally keyboard	(1) Paper tape. 20 characters/sec. (2) Line printer 108 words/min, 12 characters/word	Approx 3 kW	Desk	£20 000	Scientific an
ether with 16 e word nickel delay	Paper tape or punched card reader	Paper tape punch	Approx 7 kVA	150	£25 000	General mat scientific, sta design work aircraft, che other industr
ether with 16 e word nickel delay	Paper tape or punched card reader	Paper tape punch	Approx 11 kVA	200	£35 000	General mat scientific, sta design work aircraft, che other industr
ore store	Paper tape or punched card reader	Paper tape punch	3 kVA	80	Available on application	(1) General business arit (2) Process c data logging
ediate access store of ced to form a matrix cumulating registers gramme currently in 2 and 16 384 words nal store. Any drums may be used. tic tape decks with a exceeding 13 million llion alpha-numeric write rate of 20 000	Punched paper tape reader, punched card reader	Teleprinter/electric typewriter, paper tape punch, on-line printer, off-line printer, card punch	5–15 kW	600–1200	£100 000–£200 000	Data-proces
-4096 words of 37 bits torage; cycle time ed store—64 words of pacitor storage; cycle heral storage— is used in off-line ast start-stop one-inch grate the system. Four- pe is used for bulk perate at 20 000	Off-line (a) Direct keyboard entry to magnetic tape via an input unit. Up to 112 keyboards can be connected to one unit (b) Punched card or paper tape to magnetic tape converters	Off-line (a) Line-printer from magnetic tape (b) Punched cards from magnetic tape (c) Tabulator from punched cards On-line (a) Both forms of magnetic tape (b) Line printer; and (c) Punched cards or paper tape	Varies with size of installation. Average of 20 kVA exclusive of tape unit motors	About 200	Not yet available	Data-proces scientific
e with a capacity of 402 eed magnetic drum s. (3) Magnetic tape rage	(1) 60-column punched cards at 200 cards/min (2) High-speed paper tape input at 850 characters/sec	(1) 64-column punched cards at 107 alpha-numeric characters/sec and 1280 bits/sec. (2) Paper tape at 30 characters/sec, i.e. 210 binary digits/sec with 7-hole punching facilities	9·3 kVA without mag. tape. 20·3 kVA with 2 twin mag. tape units	500	Basic unit £50 000	Scientific

APPLICATIONS	REMARKS AND SPECIAL FEATURES
ercial	
ercial and ic	
ercial	The entry is a brief indication of the form of the first machines to be built
l purpose	General purpose usability and range of input-output equipment
fic, commercial, al	Versatility for both scientific and commercial use. Large range of input-output equipment
fic and statistical	Ease of programming and fault finding
l mathematical, ic, statistical and work in optical, , chemical and ndustries	Magnetic film available as extra backing storage
l mathematical, ic, statistical and work in optical, , chemical and ndustries	The 402F computer contains fixed point and floating point arithmetic units. It can calculate in floating point at the same speed, using the same order code as for the 402E. Magnetic film available
neral research, s arithmetic. cess control and gging systems	Transistorized, mag. core logic. By addition of special input-output equipment it can be used in process control applications. Physically small, low power consumption
rocessing	Mag. cores and transistors throughout. Simple instruction code for ease of programming. Separate buffer stores for each item of peripheral equipment
rocessing and ic	The whole system of peripheral equipment, tape units and central computer can be controlled from the computer programme as well as a control desk. A comprehensive programme interrupt system simplifies programming and ensures minimum time wastage in organizing data flow. Control time sharing is extensively used in the central computer to allow such operations as input and output (via up to four parallel channels) and computing to proceed simultaneously
fic	Deuce II similar to Mk I, except intended to be central unit of data-processing system

The Metrovick 950 is transistorized which accounts for its small size and power consumption

Information in computers is often stored on magnetic drums similar to this one from a Hollerith 1202

ANAL COMP

Air Trainers Link Ltd.

There is no standard computer but fr large, complicated electromechanical have been built. There are four standa units available include sine-cosine po operated strip potentiometers, bi-di clutches, servo drive units and stabiliz MAC (Mechanical Analogue Computer) computer that was originally designed poses. The computer is built up from dardized computing units. The resolvin 1 part in 3000. The capacity is up to f four multiplications. The input and out a strip of paper. The components of individually or in the form of a kit.

E.M.I. Electronics Ltd.

The EMIAC II analogue computer. complexity can be built up by using modules. Each module consists of 18 o or functional units; 18 C-boxes; a panel; a removable 24 unit potentiome and display panel; a relay frame; and reference supplies. The price of each m

The printed circuit d.c. amplifiers ha gain of 7×10^6; a maximum output bandwidth <1 db down at 20 kc/s (as and 0·1 pc accuracy up to 50 c/s at 1

The time division electronic multipli has an accuracy of 0·1 pc full scale or the greater. Inputs up to 50 c/s may be

The display can be on a 3 in. built-i a 10 in. separate oscilloscope. Each m panel but a number of modules can b a central control panel. The compu repetitive working.

Electronic Associates Inc.

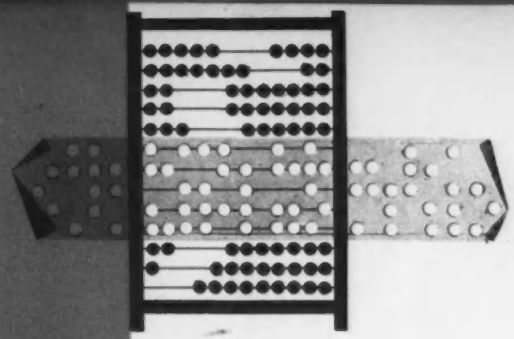
231R PACE (Precision Analogue Con This unit includes 20 amplifiers, 20 po sistorized digital voltmeter (100 readi necessary control, patching and checki with the power supplies. The basic capa by expansion equipment to 100 am tiometers, 20 servo-multipliers or re element groups, 20 limiters and 10 amplifiers. An automatic extended read automatically scans problems programm and prints out these values on paper readings/sec. The price of the basic uni additional group of 20 amplifiers cost

The amplifier package contains four amplifiers, with a 0·01 pc gain accura peak noise and $<0{\cdot}1°$ phase shift at 1 gain is about $1{\cdot}35\times10^8$, the main amp of 30 000 and the stabilized amplifier output capacity is ±100 V at 30 mA. grator drift is 3·6 mV/min and the fr 3 db down at 25 kc/s.

A choice of three types of servomu type 26-7N series with medium accu response; type 26-7M series with hig and a slower frequency response; an The latter model has a medium accu frequency response (25 c/s). There are multiplier.

An automatic digital input-outpu allows all potentiometers and diode fu be automatically programmed by keyb electric typewriter.

ANALOGUE COMPUTERS



CONTROL SURVEY 5

COMPUTERS—1959

The analogue and digital computers in this survey are of the general-purpose type and range in size from desk models to those data-processing systems which occupy several rooms. Only a brief description of the analogue computers has been given as there are few standard models, the majority being constructed to a customer's requirements

nk Ltd.

d computer but from the components electromechanical analogue computers ere are four standard amplifiers. Other ude sine-cosine potentiometers, servo-tentiometers, bi-directional magnetic units and stabilized power supplies.
Analogue Computer) is a general-purpose originally designed for educational pur-r is built up from a number of stan-units. The resolving power is better than capacity is up to four integrations and The input and output are recorded on he components of MAC are available e form of a kit. *Tick* **No 162** *on reply card*

ics Ltd.

alogue computer. A computer of any built up by using the basic units—ule consists of 18 operational amplifiers ; 18 C-boxes; a removable prepatch 24 unit potentiometer panel; a control relay frame; and the power and 100 V The price of each module is £2500.
lt d.c. amplifiers have an open-loop d.c. maximum output of 100 V 10 mA; a down at 20 kc/s (as unity gain summer) up to 50 c/s at 10 times gain.
electronic multiplier unit (type ACM1) 0·1 pc full scale or 25 mV, whichever is up to 50 c/s may be used.
be on a 3 in. built-in oscilloscope or on cilloscope. Each module has a control r of modules can be linked together by panel. The computer is designed for
Tick **No 163** *on reply card*

ociates Inc.

sion Analogue Computing Equipment). 20 amplifiers, 20 potentiometers, a tran-oltmeter (100 readings/sec) and all the patching and checking facilities together plies. The basic capacity may be enlarged pment to 100 amplifiers, 150 poten-o-multipliers or resolvers, 20 passive 0 limiters and 10 transistorized relay matic extended read-out system (AERO) problems programmed on a patch panel e values on paper tape at 5 complete rice of the basic unit is £6600 with each f 20 amplifiers costing £2000.
ckage contains four printed circuit d.c. 0·01 pc gain accuracy, <2 mV peak to ·1° phase shift at 100 c/s. The total d.c. $\times 10^8$, the main amplifier having a gain stabilized amplifier a gain of 4500. The ±100 V at 30 mA. The maximum inte-mV/min and the frequency response is /s.
e types of servomultiplier is available: with medium accuracy and frequency 7M series with high accuracy (0·04 pc) uency response; and type 16-7S series. has a medium accuracy and very high (25 c/s). There are two types of electron

digital input-output system (ADIOS) meters and diode function generators to rogrammed by keyboard, paper tape or

Metropolitan-Vickers Electrical Co. Ltd.

The Metrovick analogue computer consists basically of a cubicle containing ten operational amplifiers, ten function units and ten potentiometer units; a power unit, and a display unit. The size of the machine may be increased by the addition of extra amplifier cubicles and power units. The machine may be used for continuous operation or at any of the five repetition rates of from one half to ten seconds. The mode of operation is selected on the display unit where the output is displayed on a two-beam long-persistence 5 in. cathode ray tube. The details of the specifications have not been settled.
Tick **No 160** *on reply card*

Saunders-Roe Ltd.

The company do not make a standard analogue computer other than the Miniputer, but make a large range of standard units.

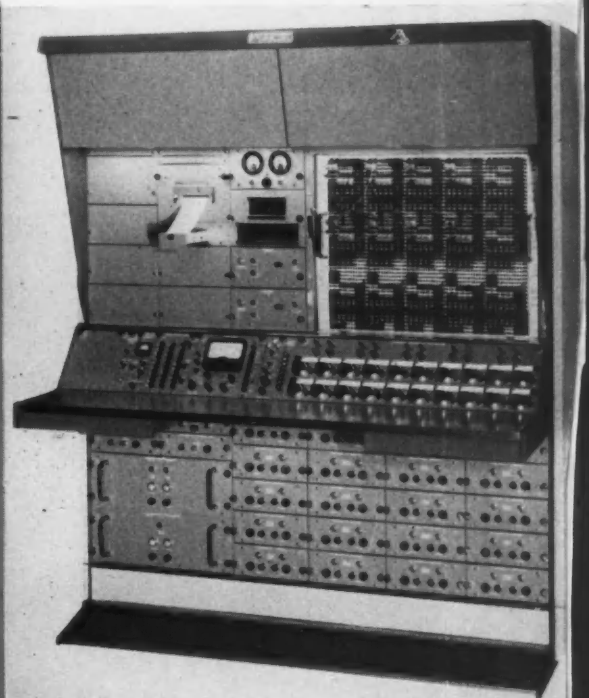
The computing amplifier is a double circuit unit comprising a high gain, drift corrected channel, and a separate unity gain drift compensated channel for sign reversal. The gain is 10^4, 6 db down at 1 kc/s. The drift, referred to the input grid is <1 mV over 8 h. The output range is ±50 V at 10 mA.

There are two multipliers offered, a quarter-squares multiplier and a slow speed version. Other units available are limiters, diode function generators and stabilized power units. The display unit consists of a 6 in. double beam cathode ray tube, or a pen recorder unit which provides two independent channels of pen recording. The computer is suitable for single shot or repetitive working (5, 10, 25 or 50 sec).

The Miniputer is a fixed-capacity desk computer that is only suitable for linear problems. The computer itself is in a box about 11×16×20 in. and the power supplies are in a separate box of similar size. The capacity is 10 amplifiers and 20 coefficient potentiometers.

The computing amplifier has a built-in sign reversing stage. The gain is 5×10^8 and the output with a 12·5 kilohm load is ±50 V. The short term drift is about ±10 mV. The potentiometers have a value of 50 kilohm (±1 pc).

The output display is on a double-beam cathode ray tube.



The 231R is an advanced analogue computer with many useful features

Tick No 148 on reply card						instruction. All arithmetic operations are fixed point, but floating point routines are available	
Ferranti Ltd Tick No 149 on reply card	Mercury electronic computer	1 Mc/s	Binary	10, 20, 40 binary digits	Single address	Serial operation, parallel storage, floating point. Mult'n 300 μ sec. Add'n 180 μ sec	(1) High-speed store (magnetic cores) 1(words. Immediate access. (2) Main stor (mag. drum) with a capacity of 32 768 words
Ferranti Ltd Tick No 150 on reply card	Pegasus electronic computer	333·33 kc/s	Binary	39 binary digits	Single address	Serial, fixed point. Mult'n 2000 μ sec. Addition 300 μ sec	(1) High-speed store (nickel delay line) capacity of 55 words. Immediate access. (2) Buffer store (nickel delay line) with capacity of 32 words. (3) Main store (ma netic driven) with a capacity of 7168 wo
Ferranti Ltd Tick No 151 on reply card	Perseus electronic computer	333·33 kc/s	Binary	72 binary digits	Single address	Serial, fixed point. Mult'n speed varies with number of digits. Addition 234 μ sec	(1) High-speed store (delay line) with capacity of 1024 words. Access time 1·8 msec. (2) Buffer store (delay line) w capacity of 32 words. (3) Main store (m tape) with an unlimited capacity
IBM United Kingdom Ltd Tick No 152 on reply card	IBM 305 Ramac (random access memory accounting) data-processing system		Binary coded decimal	Visible word-length operation	Single-address stored programme and wired panel	Serial. Mult'n: 30 msec for first multiplier digit, plus 10 msec for each additional multiplier digit. Div'n: 40 msec for first quotient digit, plus 20 msec for each additional quotient digit	(1) Mag. drum in processing unit. (2) M core storage unit holding 100 character used for all transfers of data. (3) The 3 systems may contain one or two 350 di storage units. Each unit has a capacity 5×10^6 alpha-numerical characters, stor on 50 disks, with a movable access arm controlled by the programme, for readi or writing
IBM United Kingdom Ltd Tick No 153 on reply card	IBM 604 electronic calculator		Binary	Minimum 8 digits	Wired programme	13 digit counter	Total 133 positions
IBM United Kingdom Ltd Tick No 154 on reply card	IBM 650 data-processing system		Binary	10 decimal digits + sign	Two addresses	Serial, add'n, subt'n, mult'n, div'n, 7800 add'ns or subt'ns/min. 5000 10×10 mult'ns/min. 3700 $20 \div 10$ div'ns/min. 138 000 logical decisions/min	(1) Immediate access (magnetic core) u 653 with a capacity of 600 digits. (2) M drum with capacity of 20 000 ten-digit words. Av. access time 1·2 msec. (3) Di storage—up to 4 units each with a capa of 6 000 000 digits
Leo Computers Ltd Tick No 155 on reply card	Leo II computer	525 kc/s (main computer)	Binary	19 or 39 bits including sign, and duplicate actions for each length	Single address (may be modified by one of 3 registers) including divide, square root, scale, collate, augment and special data sum check actions	Serial fixed point. Operation times including access: addition 0·34 msec from immediate access register, 0·66 msec from main store; multiply 0·66–3·5 msec from main store; divide 3·5 msec from main store	(1) Immediate access registers, 14 words 39 bits. Mercury delay line type with ze effective access. (2) Main quick access s of mercury delay line type with average access time of 0·16 msec. Capacity is 20 words (19 bits each). These may be tak pairs to form words of 39 bits. (3) Buff store of mercury delay line type with average access of 0·16 msec. Capacity o up to 288 words of 19 bits. (4) Ancillar store. Drums of 16 384 words each. Ca up to a total of 65 536 words of 19 bits
Metropolitan-Vickers Electrical Co Ltd Tick No 156 on reply card	Metrovick 950 digital computer	57 kc/s	Binary	32 binary digits (instructions and numbers)	32 two-address instructions, including add'n, sub'n, mult'n, and logical operations	Serial adder-subtractor. Fast multiplier forms 64-digit product in 8 word periods	(1) A B-line consisting of 8 single lengt words. These may be used to modify instructions, as quick access stores, and single length accumulators with additio subtraction facilities. (2) Main store 40 words; mean access time 10 msec. This may be reduced by optimum programm Division by programming
Metropolitan-Vickers Electrical Co Ltd Tick No 157 on reply card	Metrovick 1010 data-processing system		Binary	Short numbers 13 digits. Instructions 22 digits. Long numbers 44 digits	22 digit instructions	Fully parallel mode. Fixed and floating point	(1) Immediate access store (mag. core) capacity of 2048 or 4096 words (44 dig The access time is 3½ μ sec. (2) Mag. d (type 972) auxiliary storage, capacity o 44-digit words. Magnetic drum (type 9 with a capacity of 60 000 44-digit word 3-word blocks stored in parallel on 132 tracks
The National Cash Register Co Ltd Tick No 158 on reply card	National-Elliott 405 data-processing system	333 kc/s	Binary	32 binary digits + 2 gap digits	Single address—two instructions to a word	Single word length accumulator, with facilities for double-length multiplication. Separate (non-addressable) registers for use in multiplication and division	Nickel delay lines (up to 512 words) Magnetic disk (16 384 words) or magne drum (4096 words) Magnetic films (approx. 282 000 words per film)
Powers-Samas Accounting Machines (Sales) Ltd Tick No 159 on reply card	P.C.C. (Programme Controlled Computer)—an electronic digital computer	40 kc/s	Denary	16 + sign and decimal/sterling indicator	Two address	Mult'n, div'n, add'n, sub'n and various logical conditions	(1) 6 immediate access stores of 20 nu (each with 16 sterling or decimal digits (2) Main store on magnetic drum of 1(numbers (each with 16 sterling or deci digits). The immediate access stores an main store are incorporated on the same
Powers-Samas Accounting Machines (Sales) Ltd Tick No 160 on reply card	Pluto data-processing system	330 kc/s	Denary	38 binary digits + sign	Two address	Multiplication is carried out at 2 msec; calculation and addition at 0·3 msec, which includes a self-checking operation	Immediate access store of 8000 words. and nickel delay lines. External on mag tape, perforated tape and punched card
Standard Telephones & Cables Ltd Tick No 161 on reply card	Stantec-Zebra electronic digital computer	128 kc/s	Binary	33 binary digits (includes 1 sign digit)	Instruction code is based on the use of 15 functional digits each having a logical operation in the machine	Serial. Add'n and sub'n 312 μ sec; mult'n 11 msec; div'n 35 msec. An average operational time of all operations is 2 ms	(1) 12 immediate access stores, each of word length. (2) Magnetic drum storag 8192 words

		facilities	with 2 twin mag. tape units			
e (magnetic cores) 1024 access. (2) Main store capacity of 32 768	(1) Paper tape at 300 characters/sec (2) Punched cards at 200 cards/min (3) Magnetic tape at 1400 words/sec	(1) Paper tape at 240 characters/sec (2) Punched cards 100 cards/min (3) Magnetic tape at 1400 words/sec	45 kVA (depending on ancillaries)	1000	Basic £100 000	Scientifi
e (nickel delay line) with ds. Immediate access. ckel delay line) with ds. (3) Main store (mag- capacity of 7168 words	(1) Paper tape at 200 characters/sec (2) Punched cards at 200 cards/min (3) Magnetic tape at 600 words/sec	(1) Paper tape at 240 characters/sec (2) Punched cards 100 cards/min (3) Magnetic tape at 600 words/sec	18·5 kVA	2000	Basic £45 000	General
e (delay line) with ords. Access time r store (delay line) with ds. (3) Main store (mag. nited capacity	(1) Paper tape at 200 characters/sec (2) Punched cards at 200–300 cards/min (3) Mag. tape at 427 words/sec	Mag. tape at 427 words/sec	45 kVA (depending on ancillaries)	500–1000	Basic £300 000	Office
processing unit. (2) Mag. olding 100 characters, ers of data. (3) The 305 in one or two 350 disk unit has a capacity of erical characters, stored movable access arm programme, for reading	125 punched cards/min using 380 console (input, output and monitoring unit)	(1) The 370 printer can print up to 80 characters on an 8 in. line. Speed varies from 30 lines of 80 characters/min to 80 lines of 20 characters/min. (2) The 323 card punch can punch up to 100 cards/min. (3) Using the typewriter on the console	Approx. 15 kVA	400 approx	Basic £65 000	Commer control, tions, co service,
	Punched card unit 521 with a speed of 100 cards/min	(1) Punched card unit 521 with a speed of 100 cards/min. (2) Printed line using the 421 accounting machine. 150 lines/min. The 421 may be disconnected from the 604 for use as an independent accounting machine	About 75 kVA	100–150	£128 000	Scientifi processi
ss (magnetic core) unit of 600 digits. (2) Mag. of 20 000 ten-digit time 1·2 msec. (3) Disk nits each with a capacity	(1) Punched card unit 533 has two feeds—one reads input data and instructions, the other punches output results. 200 cards/min (2) Punched card input from a modified IBM 421 accounting machine. 150 cards/min (3) Mag. tape unit writes at 75 in/sec from a 2040 ft tape with a density of 200 characters/in. Up to 6 units	(1) Punched card unit 533 has output of 100 cards/min. Punched card unit 537 has output of 155 cards/min. (2) Magnetic tape with output similar to the input. (3) Printed line at 150 lines/min with 100 printing positions/line. This uses the unit described under Input (2)	Normal usage 20–70 kVA	250–1500	From £70 000	All type and scie
ss registers, 14 words of elay line type with zero) Main quick access store ine type with average msec. Capacity is 2048 n). These may be taken in ds of 39 bits. (3) Buffer elay line type with ·16 msec. Capacity of f 19 bits. (4) Ancillary 384 words each. Capacity 536 words of 19 bits	Up to 4 operating simultaneously (1) Paper tape. 200 rows/sec. (2) Punched cards (either punched in binary or any 2 hole alpha code). 200 cards/min. (3) Magnetic tape. Up to 8 decks—peak rate 10 000 digits/sec—sustained Simultaneous reading and writing including check at separate head, 4 000 digits/sec	Up to 3 operating simultaneously (1) Punched cards (either punched in binary or any 2 hole alpha code). 100 cards/min. (2) Line printer. 140 printing positions, 50 different characters, 4 plugboard layouts. 300 lines/min	50 kW	1200–1500	Basic £80 000–£100 000	Data-p
ting of 8 single length be used to modify ick access stores, and as mulators with addition and es. (2) Main store 4096 ss time 10 msec. This time y optimum programming. amming	Photoelectric tape reader (Metrovick Type 960) capable of reading 5-hole punched paper tape at up to 250 characters/sec, stop/start	Punched paper tape at 25 characters/sec, or printed page at 7 characters/sec or both at 7 characters/sec	6 kVA	150	£18 500	Scientifi
ess store (mag. core) r 4096 words (44 digits). 3½ μ sec. (2) Mag. drum y storage, capacity of 8192 agnetic drum (type 971) 60 000 44-digit words in red in parallel on 132	(1) Metrovick (type 960) paper tape reader. 5 channels at 250 characters/sec. Metrovick (type 961) paper tape reader. 5, 6, 7 or 8 channels at 1000 characters/sec. (2) Powers-Samas card reader. 540 40-column cards/min. Hollerith card reader. 600 80-column cards/min	(1) Creed 300 high speed punch. 300 characters/sec. 5, 6, 7 or 8 channel tape (the Creed 25 Reperforator may also be used) (2) Powers-Samas Samastronic line printer. 300 lines/min with 140 characters/line	2 kVA including auxiliaries	600		Data-p real-tim control, solving scientifi problem
(up to 512 words) 384 words) or magnetic s) pprox. 282 000 words	Paper tape (150–180 characters/sec) prepared by either perforator or an attachment or punched cards—Hollerith/IBM or Powers-Samas (400 cards/min)	Paper tape. Magnetic film (up to 300 characters/sec) converted off-line to paper tape. Magnetic film (up to 1440 lines/min) to actuate magnetic film controlled line printers (300 or 600 lines/min)	15–35 kW	20×30 (approx. average)	£50 000–£200 000 (including ancillary equipment)	Comme scientifi
ccess stores of 20 numbers rling or decimal digits). magnetic drum of 160 ith 16 sterling or decimal diate access stores and the orporated on the same drum	By punched cards of 65-columns or 80-columns normal capacity which, with interstage working, provide respectively up to 130 or 160 numerical or alphabetical columns of input per card. Normally 120 cards/min	By punched cards of 65-columns or 80-columns normal capacity which, with interstage working, provide respectively up to 130 or 160 numerical or alphabetical columns of input per card. Normally 120 cards/min	15 kVA	220	£20 000	Comm
store of 8000 words. Drum ines. External on magnetic ape and punched cards	Paper tape at 300 characters/sec Punched cards at 480 characters/sec Magnetic tape at 9225 characters/sec	Paper tape at 33 characters/sec Punched cards at 192 characters/sec Magnetic tape at 9225 characters/sec	30 kVA (average)	Typical installation requires about 1500	Basic cost is £100 000 and an average installation costs £180 000	
ccess stores, each of 1 Magnetic drum storage of	Punched paper tape with a maximum speed of 200 characters/sec. One input device is normally provided. The machine is designed to work with several input devices in parallel if such an arrangement is required	Two output devices are normally provided (1) Punched paper tape with a speed of 50 characters/sec (2) Direct printing at a speed of 7 characters/sec	5 kVA	200–300	£25 000 budgetary price	Mather

ien'ific	Employs plug-in construction and printed circuits
ne l purpose	Employs plug-in construction and printed circuits
fi :	Employs plug-in construction and printed circuits
) mercial, air traffic ol, seat reserva- , coastguard ce, etc	Additional access arm available. Can store programme instructions (a maximum of 200—further instructions may be stored on the magnetic disks) and information being processed: with input-output areas for simultaneous operation
cie ntific and data-ocessing	70 programme steps. Special sterling storage. Step repeats possible. Calculating and checking on same run
ll types of commercial nd scientific work	Starting conversion automatic. Symbolic language programming. The 421 printer will list information, send data into the 650 system to be processed, and accept results from the same system to be printed, stored or accumulated. The printer can be disconnected to operate as an independent accounting machine
Data-processing	Provision for automatic conversion and re-conversion between binary, decimal and sterling notations, arranging in addition for suppression of all non-significant zeros, insertion of signs and printing or punching of numbers in true decimal form
Scientific	Full transistorized arithmetical control unit with printed plug-in boards, leading to a small size and low power consumption
Data-processing and eal-time process control, also capable of olving complex cientific and engineering roblems	Transistorized. A data scanner transfers information between the mag. core store and all ancillary equipment, which allows relatively slow peripheral equipment to be connected on line to a fast computer without delaying computation by printing out, etc
Commercial and cientific	Automatic conversion facilities from telecode or decimal to binary on input and reconversion on output. Time-sharing ability between units. Modular construction. The computer is manufactured by Elliott-Automation Ltd
Commercial	Designed for integration with orthodox punched card systems and functions entirely with punched cards. Has automatic programming facility which does not occupy storage capacity
	The first of these machines is now approaching completion and is announced for sale for the first time
Mathematical	A salient feature of the Stantec-Zebra computer is its powerful and flexible programming code. This is claimed to result in a computer physically smaller, and hence less expensive, than machines of comparable ability

The Burroughs E101 is easy to programme and occupies little space

The Elliott 402 has been used on a wide variety of mathematical and scientific work

The digital computer is the left-hand unit in this view of the IBM 650 data processing system

Plug-in construction and printed circuits are used in the Pegasus computer

allows all potentiometers and diode be automatically programmed by k electric typewriter.

The 221R computer is a some sophisticated version of the 231R. accuracy, amplifiers and non-linear in the same type of console. However out to 60 amplifiers instead of 100 a AERO or problem check features. T approximately £3800. The expansio fiers cost £2000.

Elliott Brothers (London) L

G-PAC (General Purpose Analogu The single linear model consists corrected d.c. amplifiers (or their e housed in a cabinet 6 ft 9 in. hig 1 ft 10½ in. deep. The list price is £ amplifiers.

The d.c. amplifiers have been analogue computing. Drift correct chopper circuit employing an a.c external gain is unity, the amp response which is flat within 0·1 d negligible phase shift. The d.c. gain and on open-loop is 25 000, wit 5×10^6. The maximum output volt of 10 kilohm is ±100 V, with a loa it is ±30 V. The drift with unity

Also available are arbitrary fu units, logarithmic multipliers, servo dead zone units, squarer units and fi

The computer has a single shot the output being on a customer's

Miniac is a compact linear com amplifiers, designed for single-shot are similar to the standard ones simple problem patching system i circuit symbols printed on the fac The price is about £1300 and it ha requirements for a small training

English Electric Co. Ltd.

LACE (Luton Analogue Computi number of self-contained compute contains: (1) 12 drift corrected d.c. purpose function generators; (3) (4) 18 coefficient potentiometers; (6) relays, block chassis, patch par of an average installation is £520

The amplifier unit comprises 2 gain drift-corrected amplifier is int grating, etc. It has a gain of 65 0 d.c. to d.c. gain is 1500 with an 108 at d.c. The drift is $<100\mu$V/h The output is 50 V across 10 kilob primarily intended for sign reversi a gain of 65 000. The drift is <2 m grid. The output is ±50 V across are a function generator and a

The display is on a 4 in. diame sweep time range being 5 to 0·05 in. Single shot or repetitive operation

Fairey Aviation Co. Ltd.

The Fairey electronic analogue co unitary basis to fit standard 10× arrangement comprises a control distribution equipment for up to fi rs, but the capacity can be ex basis of the computer is the comp 12 standard d.c. operational am computer can be obtained on ap

The printed circuit computing form of a thin plug-in unit and co gain d.c. amplifier which is drift-c converter and an a.c. amplifier. >60 000 at d.c., >8000 at 1 kc/s >750 and the total d.c. gain is 45 is $<100\mu$ V. The phase lag at 17½. The output is 100 V 10 mA. S or recorded on multi-channel c quick response direct-writing reco

ometers and diode function generators to programmed by keyboard, paper tape or r.

mputer is a somewhat smaller and less sion of the 231R. It has exactly the same ers and non-linear components and is built f console. However, it can only be expanded ers instead of 100 and does not contain the m check features. The basic model sells for 3800. The expansion groups of 20 ampli-

Tick No 164 on reply card

ers (London) Ltd.

l Purpose Analogue Computer)
ar model consists basically of 20 drift-nplifiers (or their equivalent in other units) binet 6 ft 9 in. high, 2 ft 2½ in. wide and . The list price is £4400 for a cabinet of 20

olifiers have been designed for real-time uting. Drift correction is carried out by a employing an a.c. amplifier. Where the s unity, the amplifier has a closed-loop is flat within 0·1 db up to 400 c/s and has shift. The d.c. gain without drift correction oop is 25 000, with drift correction it is ximum output voltage for a load resistance ±100 V, with a load resistance of 3 kilohm e drift with unity external gain is ±1 mV. e are arbitrary function generators, delay ic multipliers, servomultipliers, limiter units, squarer units and fixed function generators. r has a single shot synchronized time base, g on a customer's oscilloscope or recorder.

compact linear computer housing up to 10 ned for single-shot operation. The amplifiers the standard ones used in the G-PAC. A patching system is used, with appropriate printed on the face of the patching board. out £1300 and it has been designed to meet r a small training analogue computer.

Tick No 165 on reply card

ctric Co. Ltd.

Analogue Computing Engine) consists of a -contained computers or bricks. Each brick drift corrected d.c. amplifiers; (2) 2 general-on generators; (3) 2 electronic multipliers; nt potentiometers; (5) 6 diode limiters; and k chassis, patch panel and supplies. The cost installation is £5200.

r unit comprises 2 d.c. amplifiers. The high cted amplifier is intended for summing, inte- has a gain of 65 000, 80 db at 100 c/s; the in is 1500 with an overall gain better than drift is $<100\mu V/h$ referred to the input grid. 50 V across 10 kilohm. The other amplifier is ded for sign reversing and as a buffer. It has 0. The drift is <2 mV/h referred to the input ut is ±50 V across 10 kilohm. Also available generator and a multiplier.

is on a 4 in. diameter cathode ray tube, the ge being 5 to 0·05 in. in 7 steps (2 pc accuracy). repetitive operation.

Tick No 166 on reply card

ation Co. Ltd.

ctronic analogue computer is designed on a o fit standard 10×72 in. racks and the basic omprises a control rack, housing control and uipment for up to 96 operational d.c. ampli- capacity can be extended considerably. The mputer is the computing panel which houses l.c. operational amplifiers. The cost of the be obtained on application.

circuit computing amplifier (Mk 2) is in the plug-in unit and comprises a three-stage high-ifier which is drift-corrected by a synchronous an a.c. amplifier. The d.c. amplifier gain is c., >8000 at 1 kc/s; the a.c. amplifier gain is total d.c. gain is 45×10^6. The input grid drift The phase lag at 1 kc/s (overall gain=1) is t is 100 V 10 mA. Solutions may be displayed on multi-channel cathode ray oscillographs, e direct-writing recorders, or on X-Y plotters.

Tick No 167 on reply card

is ±50 V. The short term drift is about ±10 mV. The potentiometers have a value of 50 kilohm (±1 pc).

The output display is on a double-beam cathode ray tube. Single-shot working is possible but normally repetitive is used (sweep time 10, 20 or 40 msec).

Tick No 169 on reply card

Short Bros & Harland Ltd.

The Shorts general-purpose analogue computer is in one piece accommodating the computing units, cathode ray tube, recorder, power supplies and timing and control unit. The complete console is 5½ ft high, 4½ ft wide and 2½ ft deep, the weight being 650 lb. The power requirements are approximately 1 kW at 230 V 50 c/s. The h.t. power units are stabilized to within 0·25 pc, and the h.t. to within 0·02pc. One console may be fitted with 18 linear function units and 18 scaling units or their equivalent.

The linear function unit (type C) has been designed for repetitive and continuous (or single shot) operation. On integration the open loop gain $>12\times10^6$ (12×10^5 for addition), the max. output is 50 V and the output error >0·5 V after 25 min (integrating time constant of 1·0 sec).

Other units available include a scaling unit, a continuous function unit, a discontinuous function unit, a delayed display timing unit, a variable time switch unit, a low frequency decade oscillator, a sine-cosine unit and a function square unit.

The display is on a 4-inch double-beam flat-faced cathode ray tube with 15 sec afterglow. Overall deflexion linearity is better than 1½ pc. An ink pen recorder on a 4 cm chart or a 'dry-working' camera can be supplied. The capacity of the console may be indefinitely expanded by additional units. The basic cost is about £5300 (with linear units).

Tick No 170 on reply card

Solartron Electronic Group Ltd.

SPACE (Solartron Precision Analogue Computer Equipment). This manufacturer supplies units from which an analogue computer of any desired complexity can be obtained.

The d.c. amplifier consists of a high-gain d.c. section with an economy cathode-follower output stage, and an auxiliary drift correction amplifier. The neon true-overloaded indicator provides a self-contained set zero facility. The d.c. gain is $>30\times10^6$; at 100 c/s $>10\times10^6$. The drift referred to the summing junction is >100 μV (long term); with a random daily drift of about 20 μV. The output >±100 V into 20 or 10 kilohm. The h.t. consumption (maximum at +100 V output) is +300 V at 20 mA or 31 mA, −300 V at 16 mA or 22 mA. A linear computing unit in conjunction with an amplifier like the one previously described is a basic linear 'brick', capable of 0·1 pc accuracy.

A comprehensive range of other units is available, including a crossed fields multiplier, a cathode follower unit, a dead zone/limiter unit, digital voltmeters, general-purpose servomultiplier, general-purpose diode function generator and a process response analyser.

The Minispace analogue computer (TY 864) is a self-contained console computer comprising 10 drift-corrected amplifiers, with all the input and feedback components, potentiometers, control panel, patching panel and power supplies. Non-linear elements are incorporated and expansion facilities are provided. The overall cabinet size is about 51 in. high, 20 in. wide and 30 in. deep.

The d.c. amplifiers are similar to the ones described in SPACE. Although designed as a real time computer, a repetitive switch is incorporated so that 'compute' periods of 1, 2 and 5 seconds with a 1 second reset period are obtained automatically with a trigger signal. The basic cost of one Minispace is £1500.

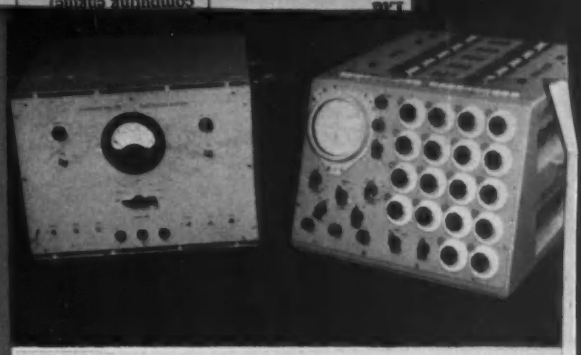
Tick No 171 on reply card

Southern Instruments Computer Division

This firm constructs a number of components for use in electronic analogue computers.

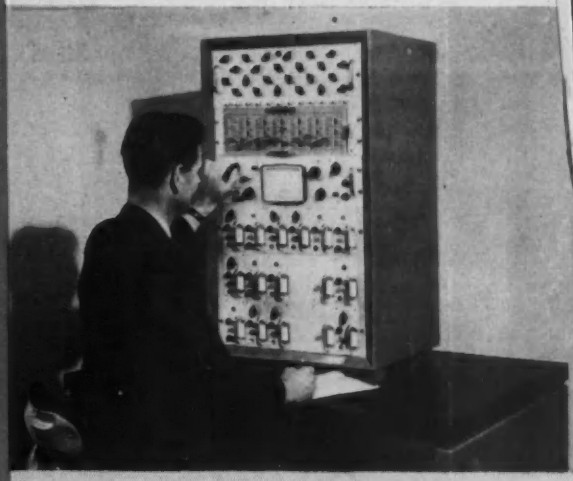
The K603 drift corrected amplifier consists of a main d.c. amplifier with a chopper relay and auxiliary amplifier to provide drift correction. It forms the basic element for adding, integrating and generation of certain types of non-linear function. The drift corrected open-loop gain at d.c. is approximately 20×10^6, without drift correction it is 30×10^3. The frequency response is 3 db down at unity gain (1 megohm resistors) on 100 kc/s. The drift referred to virtual earth is ±50 μV. Also available are the K625 function generator and the K608 crossed fields multiplier.

Tick No 172 on reply card

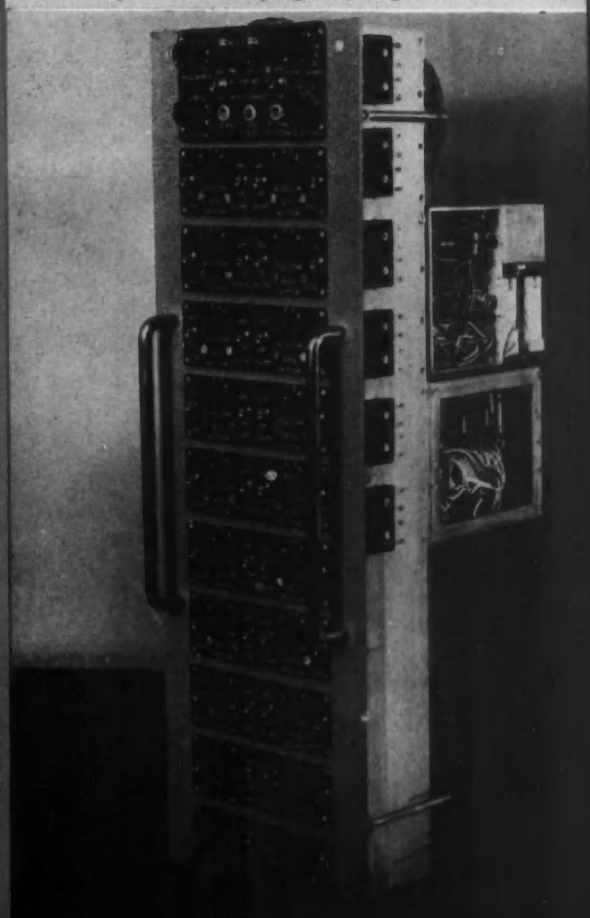


The desk-size Miniputer and its power supplies

One of the modules of the Emiac II



The Shorts continuous function unit is a typical example of modern plug-in analogue construction



ELECTRIC DRIVES AT CONSETT

by **R. MATHIESON, B.Sc.**
Assistant Chief Engineer, Consett Iron Co

Modern rolling mills demand quick-acting high-power electrical control equipment. The Consett installation does not have the new automatic control of screwdown (*News Round-up, October*), but it exemplifies modern mill drive control that has given good service for several years.

THIS ARTICLE DESCRIBES THE ELECTRICAL PLANT CONTROLLING the 44 in. slabbing and blooming mill of the Consett Iron Co in County Durham. The equipment for drives of this kind follows a fairly well-defined pattern and the Consett installation, although not new, is typical of heavy rolling-mill drives which have been put to work during the last few years.

Outline of the mill's construction

The mill itself comprises a pair of horizontal rolls through which the hot ingot is passed backward and forward, the top roll being moved downward towards the bottom roll between each pass as rolling proceeds. The mechanism for adjustment of the top roll position is known as the *screwdown*.

Other drives required for presenting the piece correctly to the rolls are the main tables and manipulators on the ingoing and outgoing sides of the mill, and a tilting mechanism on the ingoing side only. The main tables comprise a system of heavy rollers for bringing the ingot onto the mill, feeding the piece into the main rolls between the various passes and for conveying the finished material away from the mill. The four heads of the manipulators are driven by racks backwards and forwards transversely across the mill, to so position the material being rolled that it will enter the roll on the barrel, or into the appropriate groove. So that the piece can be rolled on all sides, a tilting mechanism is provided to turn it through 90°; this is built onto one of the manipulator heads on the ingoing side.

Fig. 1 shows an ingot entering the mill. The two scales of the dial indicate in inches the opening between the rolls, the inner pointer giving a fine indication of the lower reading of the two outer pointers. The higher-reading outer pointer represents the opening between the grooves in the rolls; there is a constant differential between the two fingers for the outer scale, and this represents the difference in diameter between the barrel and grooves of the rolls.

Drive requirements

Mills of this type require a combined torque on both rolls of around 2×10^6 lb-ft, and in order to achieve this, each roll is usually driven independently by its own motor. At Consett the two main motors are single-armature machines, each rated at 4000 h.p., with a speed range of 0—120 r.p.m. (with a base speed of 50 r.p.m.) and designed to deal with working overloads of 2½ times full load.

The two-motor drive has several advantages over the single-motor drive, which for so long remained accepted practice for smaller and earlier mills. It makes unnecessary the heavy pinions required for splitting the single drive to give a connexion to each roll; moreover the separate drive to each roll gives a more flexible arrangement which can be used to advantage to suit rolling technique. Clearly also the provision of high torque outputs from a single drive becomes increasingly difficult and expensive as the required demands increase in capacity. Fig. 2 makes clear the essential differences between the single- and two-motor drives.

Two operators, stationed in an elevated air-conditioned pulpit on the ingoing side of the mill, manipulate the ingot. The photograph of Fig. 1 was taken from the pulpit and represents an operator's view of the mill. The first operator controls all tables, which include the main ones immediately adjacent to both sides of the mill, approach and runout tables, screwdowns and the drive for the main rolls. The second is responsible for the operation of the manipulator heads and the tilting mechanism. As the economics of rolling depend

on the rate at which steel can be processed in the mill, the operators must be given every facility for maintaining high outputs over the whole of their working shift. To do this the controllers must be light and easy to handle, and the drives must be immediate and accurate in response to any controller movement. Because of these requirements the main drive and the drives of those auxiliaries used in manipulation of the piece during rolling are all based on the Ward Leonard principle (i.e. d.c. motors supplied by variable-voltage generators), and are backed up by quick-acting exciter systems.

The basis of the drive control

Fig. 3 is a simple schematic which illustrates the control adopted for the drive of the main rolls. The series connexion for the main machines is particularly suited to a drive of this nature as current is the same throughout the loop; it therefore

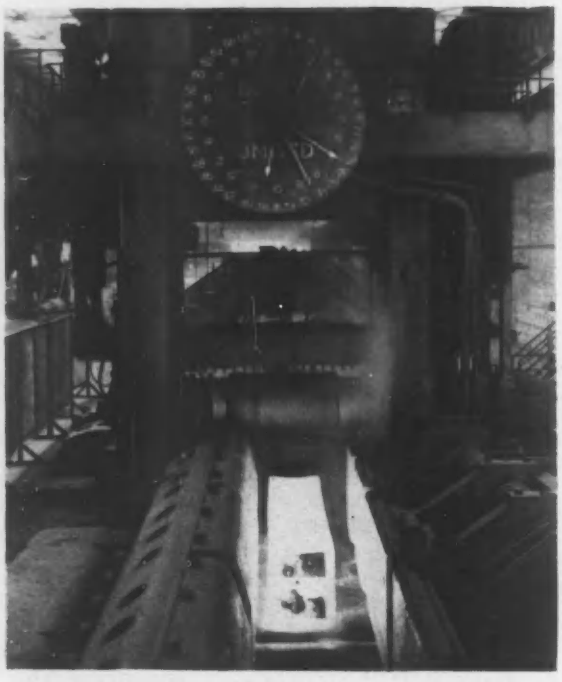


Fig. 1 A red-hot ingot starts its first pass through the Consett rolling mill

The cross-section of the ingot is approximately 2 ft square

follows that torque equalization of the two motors is an inherent characteristic of the scheme. To ensure that the speed reaction of the two motors is identical one must tie the voltage distribution round the loop, and with this in mind a connexion is made across the two halves of the circuit. This feature is necessary because of the lack of mechanical tie between the two driving motors but it will be shown later how it can be used to advantage by giving some amount of differential speed control to the two machines while they operate as free units. In this connexion it must be appreciated that a mechanical tie, though not a truly rigid one, is established as soon as a piece enters the rolls.

The generator fields are supplied by a single exciter E_3, which is a normal separately excited d.c. generator, controlled

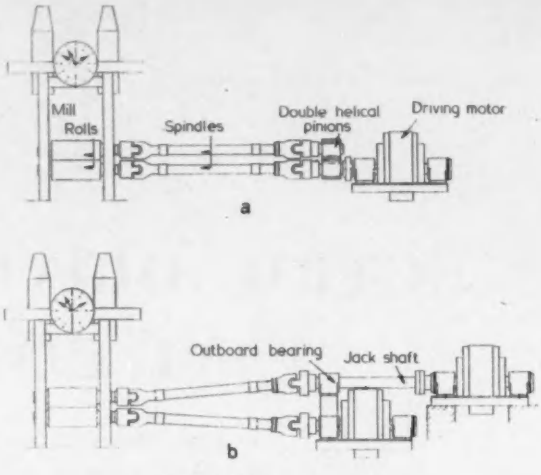


Fig. 2 Rolling-mill drives

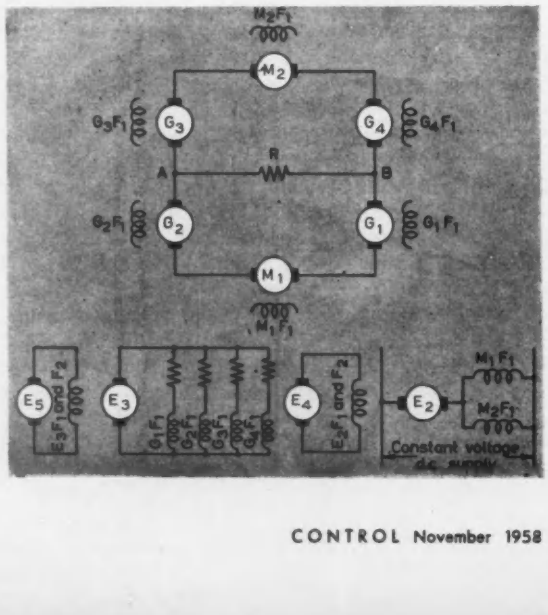
a. Single-motor b. Two-motor

by a quick-acting exciter E_5 receiving its reference from the operator's controller. Main motor field control is effected by the variable voltage bucking exciter E_2, which in turn is governed by a quick-acting exciter system E_4 similar to that for the generator voltage control.

Torque, speed, voltage and motor field characteristics for such a scheme are shown in Fig. 4 and are particularly suitable for the type of drive in question. As the section of the piece being rolled becomes smaller so its length increases; at the same time the amount of metal displaced per unit of length for each pass becomes correspondingly less so that torque requirements are lower. In the later stages of rolling higher mill speeds can be used to advantage. To attain these speeds, motor field weakening is used and the resulting reduction in available torque does not create any serious embarrassment.

The system is designed to obtain rapid response consistent with safe working loads; voltage control, overcurrent protection, automatic compounding and necessary delay systems

Fig. 3 Schematic circuit of the drive control for the main mills



are built into it—these features being made possible by tuned-field control exciters.

The tuned-field control exciters

The control exciters used at Consett are normal 4-pole d.c. generators, relying entirely on their effective excitation by changes in controlled quantities; they can regulate automatically, to accurate limits, any quantity of the output circuit because of their high steady-state amplifying properties. Fig. 5 explains the amplifying properties of these exciters.

E is a quick-response or *tuned-field* exciter governing the voltage of G, by control of generator field windings GF_1 and GF_2; EF_1 is the self-exciting series winding; EF_2 is the quick-response and temperature correcting winding; EF_3 is a control winding, in this instance used for voltage selection and known as the reference coil; EF_4 is a control winding, and is supplied with voltage output intelligence; and EF_5 represents other control windings used as required.

Basically, the exciter is a self-excited series generator operating on the unsaturated portion of its output/excitation curve. The control windings provide the necessary stabilizing action and maintain a stable output dictated by the setting of the reference.

Self-excitation is provided by EF_1, which carries the exciter output current, and with a purely resistive load, excitation due to the series winding will increase linearly with exciter volts, and is represented by the line BOR, having a slope which depends on the value of load resistance. By altering the value of R_1, the slope of OR can be changed, and thus for one critical value BOR will coincide with the straight part of the saturation curve; OR′ represents such a state. Under these

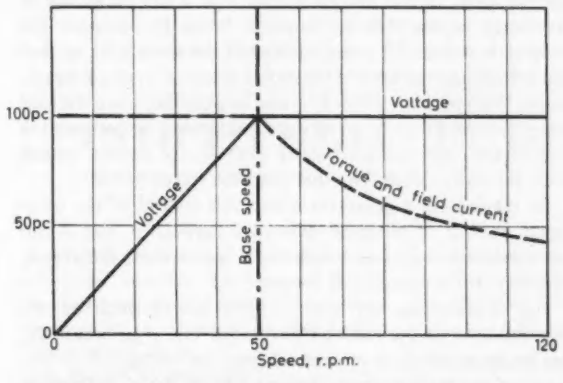


Fig. 4 Torque and speed characteristics for the drive motors, in relation to voltage and field current

circumstances the exciter is said to be *tuned* and can provide the necessary self-excitation for any set of conditions along the straight portion of the curve.

If we now add to the self-excitation a small amount $\delta\phi$ the excitation is represented by a line GH removed from OR′ by an amount $\delta\phi$, cutting the voltage curve on its curved portion, and so giving rise to a ceiling voltage V_m. Such an increment can be given by energizing the reference field winding EF_3. If, however, we can arrange for the reference field to be cancelled when a given exciter voltage has been attained, the exciter will then maintain such a voltage by virtue of its own excitation. Cancellation of the reference field can be achieved by opposing it by a suitable feedback from the final controlled output and applied to coils EF_4. In the

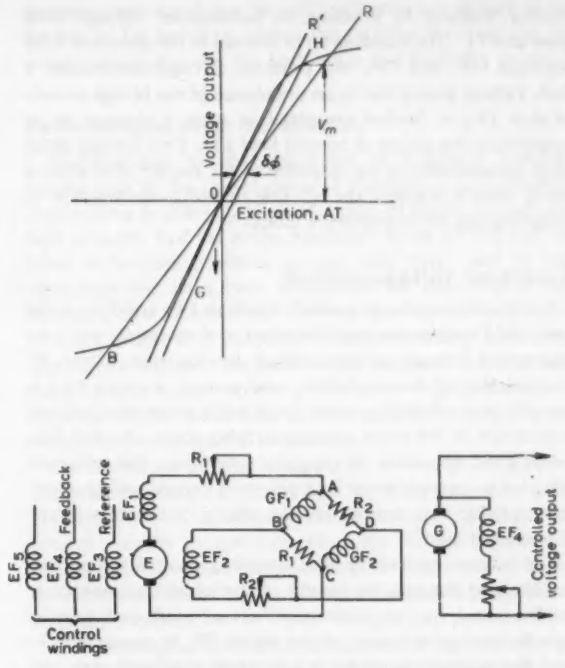


Fig. 5 How the tuned-field exciters used at Consett operate is explained in the adjacent text with reference to this diagram

conditions of Fig. 5 the feedback is a measure of the controlled voltage of G and it will be seen that by adjustment of the reference field any selected voltage can be maintained from generator G.

It can be appreciated that by using the tuned-field exciter, close control of output voltage or current is easily obtained. By converting other references such as speed and material tensions into electrical intelligence, these outputs also can be controlled just as effectively.

Compensation for heating of field coils

Any alteration in the output circuit of the exciter will adversely affect the slope of the resistance line OR′ so that the machine goes 'off-tune'. Such an effect can be brought about by heating of generator field coils GF_1 and GF_2, and in order to correct this the field coils are arranged as a bridge circuit ABCD with suitably connected resistances. The field windings GF_1 and GF_2 are made identical as far as possible; resistances R_1 and R_2 completing the bridge comprise units of negligible temperature coefficient and each have values equal to their corresponding field. Consider the machine to be tuned with windings GF_1 and GF_2 'cold'. As the temperature increases, so the winding resistance increases and the exciter goes 'off-tune'. But because the ohmic value of resistances R_1 and R_2 remains constant the bridge becomes unbalanced so that a potential is created between points B and D, the amount being a function of the resistance change of the field windings. By connecting field EF_2 across B and D, temperature compensation can be achieved and the system maintained tuned.

As the sensitivity of the exciter is dependent on keeping the tuning, the temperature-correction field clearly plays an important part, but consideration of the circuit under transient conditions shows further advantages to be gained from this winding. Thus suppose that adjustments are made to the

control winding to produce an increase in voltage from generator G. The building up of current in the generator field windings GF_1 and GF_2 will produce, through inductance, a back voltage giving rise to an unbalance of the bridge circuit, so that EF_2 is further energized in such a manner as to supplement the action of control field EF_3. This forcing effect helps considerably in the response of the exciter, and when a steady state is reached, the winding reverts to its function of compensating for temperature effects.

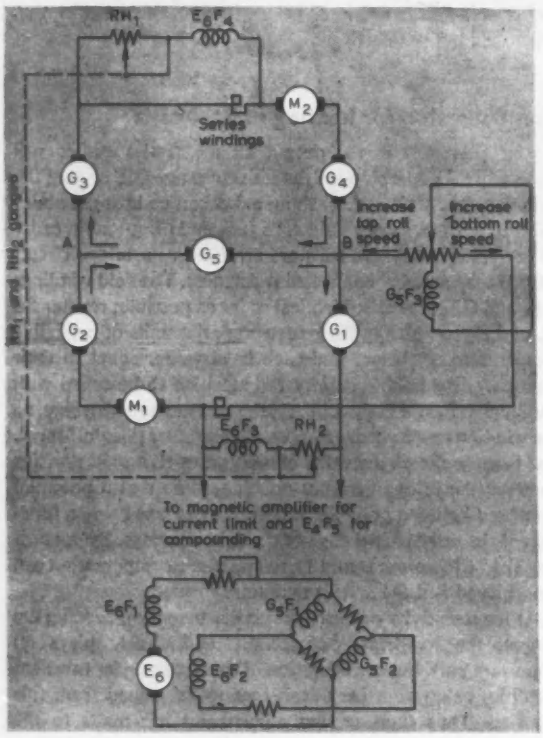
Generator voltage control

For generator voltage control, windings EF_3 and EF_4 of the tuned-field exciter are used to select and maintain any predetermined voltage as determined by the mill driver by manipulation of his controller, and control winding EF_5 is brought into service in order to provide protection against overcurrent in the main current-carrying loop. The coil EF_5 is energized by means of magnetic amplifiers, the reference being taken across motor interpole and compensating windings; suitable bias neutralizes the effects of currents below 2½ times full load.

It is interesting to note that reversing control is required for EF_5, and because the output of the magnetic amplifier is unidirectional, two magnetic amplifiers are used, each supplying a balancing resistance across which EF_5 is connected. So used, the magnetic amplifier is a relatively inefficient unit, but for the application in question the losses introduced are of no consequence and the equipment has given trouble-free and effective service.

To prevent motor field weakening when high armature currents already exist, the control field E_4F_5 is given armature current reference so that E_4F_5 overrides other control fields of exciter E_4 and so maintains motor fields

Fig 6. Differential control of mill motor speed and torque



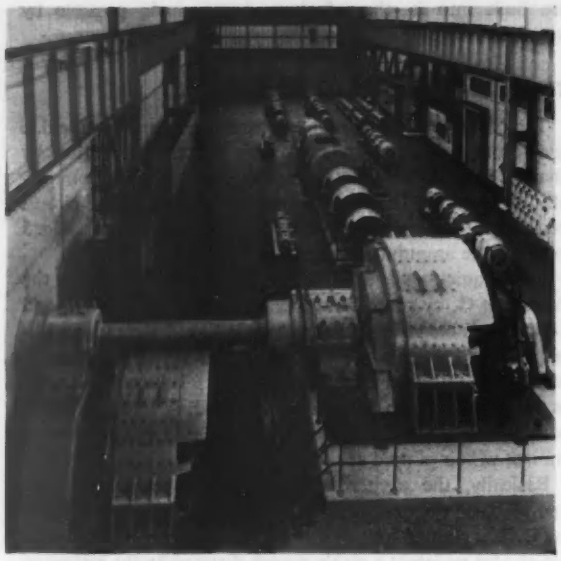


Fig. 7 The control room at Consett running down the length of the mill. The main drive motors are in the foreground, the mill itself being the other side of the partition wall on the left

M_1F_1 and M_2F_1 at their full value. By using blocking rectifiers and adjustable bias voltage one can select the level at which field weakening is permitted to take place.

Differential speed and torque control

Mention has already been made of the tie across the main current loop. This is shown in Fig. 3 as a low resistance R connected across AB, its function being to maintain the potentials at A and B at approximately the same level, so that the voltages across each of the motor armatures remain nearly equal. Without such a link it would be possible, when the mill was empty and therefore lacking a mechanical tie between the two motors, for one machine to grab all the circuit voltage and race away, while the other machine stayed at rest.

By connecting a generator across AB instead of the resistance, control of potential difference between A and B can be exercised, making available a controlled differential between motor speeds and torques.

Fig. 6 illustrates how such control can be obtained. By manipulation of the rheostat governing G_5F_5, generator G_5 can be made to add to or subtract from the voltage of the two loops of the main current-carrying circuit. Such differential is proportional to the loop voltage, and a controlled speed difference between M_1 and M_2 is therefore available by rheostat adjustment.

A measure of differential torque control is brought about by energizing fields G_5F_1 and G_5F_2 by a tuned-field exciter E_6, for which reference and feedback are related to the currents passing through the main motors. By adjustment of ganged rheostats RH_1 and RH_2, the voltage of G_5 can be held to maintain a fixed current difference in the two motor loops, the out-of-balance current flowing through generator G_5.

Auxiliary drives

While the control characteristics described are for the main motor drives, the same system of control is generally applied to the much smaller, but equally important, auxiliary drives. The main difference is that the auxiliary motors do not make

use of field weakening and thus retain their maximum torque output throughout the speed range.

It has been found in the smaller drives that without the current limit in operation the rate of response to voltage build-up is so fast that current peaks due to acceleration are greater than the machine ratings. With current limit devices functioning, voltage response becomes dependent on load current, and accelerations are kept to a maximum consistent with reasonable and preselected current values.

Again in certain auxiliary drives it is necessary to fit brakes in order to make sure that drives stay put in their standing position. Under standstill conditions with brake applied, the generator voltage due to residual magnetism causes armature currents well above acceptable levels. To overcome this, an auxiliary contact on the brake relay is used so that when the brake is applied the voltage bias in the current limit control system is short-circuited. This has the effect of making the current limit system responsive to currents of low value so that any residual magnetism is neutralized.

Layout of the electrical plant

Fig. 7 shows the building housing the electrical equipment for the Consett mill. In the foreground are the main mill motors, with their associated generator set situated down the middle of the building; immediately behind them, to the right of the main generator set, are two exciter sets (one standby), each comprising a driving motor, a d.c. constant voltage generator for general purpose use, two generators E_4 and E_5 (Fig. 3), and a further generator G_6 (Fig. 6). The motor-generator sets supplying the mill auxiliaries can be seen at the far end of the building, and in the right-hand corner are the tuned-field exciter sets for both main and auxiliary drives.

Performance since installation

Modifications to the equipment as originally installed consist only of the introduction of mechanical and electrical interlocking to prevent the overlapping of motor voltage and field changes. For the more important drives on the mill the latest techniques available at the time were used to best advantage and have been responsible for maintaining high outputs over a long period. However since the commissioning of the Consett mill considerable improvements have been made in the design of magnetic amplifiers, resulting in greater capacity and faster response. It is now largely possible to dispense with the tuned-field exciters, all control being through the medium of magnetic amplifiers.

Developments in hand and related to the drives described comprise modifications to the control of the screwdown. The first stage of this development is to introduce an automatic control whereby the operator selects the increments necessary for any roll movement. This modification lends itself to further development and the introduction of a completely programmed screwing schedule.

It is pleasing to be able to put on record that the whole of the electrical equipment for the Consett mill, which was manufactured by the English Electric Co, has now been in operation for some years and has maintained the high standard of reliability which one expects from plant of this sort.

INDUSTRIAL PUBLICATIONS

A brochure containing diagrams and tables of ratings describes the American Annin Domotor **control valve** which will be manufactured in this country by the Audley Engineering Co Ltd.
Tick **No 125** on reply card

The Addison Electric Co Ltd have brought out their first leaflet giving details of all their **equipment for wire** and cable makers. The leaflet is brief and to the point and well illustrated.
Tick **No 126** on reply card

George Kent Ltd present a nicely designed booklet, both readable and informative, on measuring and controlling **nuclear energy.**
Tick **No 127** on reply card

The first issue has appeared of Drayton News, **a news sheet** giving general news of the Drayton Regulator & Instrument Co.
Tick **No 128** on reply card

Teddington Aircraft Controls Ltd have produced an excellent white and gold **year book** which provides a concise and up-to-date collection of technical data concerning their equipment.
Tick **No 129** on reply card

The Ampex Corporation present a brochure of high quality, with good illustrations on their **digital-tape system.**
Tick **No 130** on reply card

Hilger & Watts present a booklet, containing photographs and graphs, which describes their recording **X-ray diffractometer** and fluorescence spectrometer.
Tick **No 131** on reply card

The first issue of the new Siemens Edison Swan Journal has appeared. It is well produced and very readable, containing many photographs and diagrams, together with information of a general nature.
Tick **No 132** on reply card

The Davall Gear Co, in a small pictorial leaflet, describe the process of **gear cutting.**
Tick **No 133** on reply card

Beckman Instruments Inc have produced a booklet briefly describing their wide variety of **continuous stream analysers.**
Tick **No 134** on reply card

Details and dimensions of the new hydraulic relay **speed control** for 'F' type Carter hydraulic infinitely variable speed gears are given in a brochure by Carter Gears Ltd. The publications should be read in conjunction with current technical publications on the 'F' type range.
Tick **No 135** on reply card

Negretti & Zambra have produced an exhaustive and liberally illustrated brochure on their **range of instruments.** It is also published in French and Italian. An orange-and-green-striped, 3-language leaflet deals with their pressure amplifiers and gap-measuring probe. We have also received well-illustrated leaflets on their diesel engine thermometer in Italian and German.
Tick **No 136** on reply card

PART 5

by C. M. BURRELL, M.A., B.Sc., A.M.I.E.E.
& J. K. LUBBOCK, M.A., B.Sc.
Lecturers in Department of Engineering, Cambridge University

What is control engineering?

WE SHALL QUICKLY RECAPITULATE SOME OF THE SUBSTANCE OF the last article:

If we are given an arbitrary periodic or aperiodic input we can often find its Fourier series, or the Fourier series of an equivalent periodic function whose period is long compared with the settling time of the system. By this means, we found that the system output was given by

$$y(t) = \sum_{n=-\infty}^{+\infty} C_n(jn\omega_0)\, W(in\omega_0) e^{jn\omega_0 t} \qquad \ldots (1)$$

where $y(t)$ is the output function of time

$$x(t) = \sum_{n=-\infty}^{\infty} C_n(jn\omega_0) e^{jn\omega_0 t} \qquad \ldots (2)$$

is the Fourier series for the input function of time. $T = 1/\omega_0$ is the period of the input.

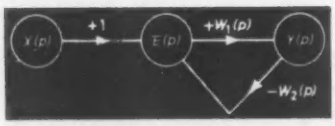


Fig. 1 The dependence diagram of a closed-loop system

Writing ω in the place of $n\omega_0$ we have: $W(j\omega)$ is the system 'vector multiplier' (a function of frequency) and may be defined as:

$$W(j\omega) = \frac{b_m(j\omega)^m + b_{m-1}(j\omega)^{m-1} + \ldots + b_0}{a_n(j\omega)^n + a_{n-1}(j\omega)^{n-1} + \ldots + a_0} \qquad \ldots (3)$$

where the system differential equation is the linear equation

$$a_n\frac{d^n y}{dt^n} + a_{n-1}\frac{d^{n-1}y}{dt^{n-1}} + \ldots + a_0 y = b_m\frac{d^m x}{dt^m} + b_{m-1}\frac{d^{m-1}x}{dt^{m-1}} + \ldots + b_0 x \qquad \ldots (4)$$

In the interests of generality (see Appendix) we prefer to write in place of $j\omega$ the symbol p and to call the function $W(p)$ a *transfer function* instead of a vector multiplier. The symbol p has already been used to indicate the operation d/dt, but in the sense in which we now use it, it is more than an operator; it is the independent complex variable of the function $W(p)$. From equation 2 we can write

$$x(t) = \sum_{n=-\infty}^{\infty} C_n(j\omega) e^{j\omega t} \quad \text{where} \quad \omega = n\omega_0$$

Likewise the Fourier series for the output time function is

$$y(t) = \sum_{n=-\infty}^{\infty} D_n(j\omega) e^{j\omega t}$$

But from equation 1

$$y(t) = \sum_{n=-\infty}^{\infty} C_n(j\omega)\, W(j\omega) e^{j\omega t}$$

whence we get

$$D_n(j\omega) = C_n(j\omega)\, W(j\omega) \qquad n = 0, 1, 2 \ldots \infty$$

Replacing $j\omega$ by p, C_n by X and D_n by Y, we have

$$Y(p) = W(p)\, X(p) \qquad \ldots (5)$$

We will call the functions $X(p)$ and $Y(p)$ the transforms of $x(t)$ and $y(t)$ respectively. These functions $X(p)$ and $Y(p)$ are the spectral distribution functions and represent the Fourier series expansion coefficients or Fourier transforms*, of the function $x(t)$ and $y(t)$ respectively. However, it should be emphasized that when we use the Fourier series expansion, $X(p)$ and $Y(p)$ are defined only at a number of discrete frequencies $p = jn\omega_0$ and these functions are not continuous functions of p as is generally the case when $X(p)$ and $Y(p)$ represent Fourier transforms.

Consider next a closed-loop system whose dependence diagram is shown in Fig. 1. The equations relating the various transformed quantities are

$$Y(p) = W_1(p)\, E(p) \qquad \ldots (6)$$

$$E(p) = X(p) - W_2(p)\, Y(p) \qquad \ldots (7)$$

Substituting (6) in (7) we get

$$\frac{Y(p)}{W_1(p)} + W_2(p)\, Y(p) = X(p)$$

Hence

$$\frac{Y(p)}{X(p)} = \frac{W_1(p)}{1 + W_1(p)\, W_2(p)} = W_c(p) \qquad \ldots (8)$$

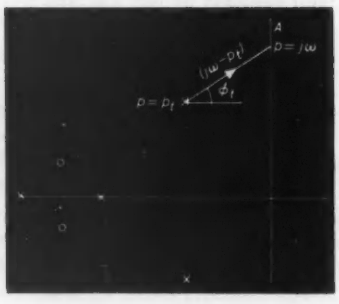


Fig. 2 A system is characterized by the locations of the poles and zeros of its transfer function on the complex p plane

* When using transformational calculus the equation 5 has a more general interpretation than indicated in the above text. See the appendix to part 4 and the appendix of this article.

$W_c(p)$ is the transfer function of the overall system relating input to output. It is called the 'closed-loop transfer function', whilst $W_o(p) = W_1(p)\,W_2(p)$ is known as the open-loop transfer function.

As an example we recall the feedback amplifier having a forward gain $A = W_1(p)$ and a feedback factor β (fraction of output which is fed back to the input). Then the overall gain $N = A/(1 + A\beta)$.

Poles and zeros of the transfer function

$$\text{Let } W(p) = \frac{B(p)}{A(p)} = \frac{b_m p^m + b_{m-1}p^{m-1} + \ldots + b_r p^r + \ldots + b_0}{a_n p^n + a_{n-1}p^{n-1} + \ldots + a_t p_t + \ldots + a_0}$$

$$= K\frac{(p - z_1)(p - z_2)(p - z_3)\ldots(p - z_m)}{(p - p_1)(p - p_2)(p - p_3)\ldots(p - p_n)} \quad \ldots (9)$$

where $K = b_m/a_n$, which is called the *gain factor*.

Then $z_1, z_2, z_3 \ldots z_m$ are called the *zeros* of $W(p)$ since they are the values of p for which $W(p) = 0$; $p_1, p_2, p_3 \ldots p_n$ are called the *poles* of $W(p)$ since they are the values of p for which $W(p) = \infty$.

Since the coefficients b_r and a_t are real the zeros and poles of $W(p)$ will be real or occur in complex conjugate pairs.

A system is thus characterized (with the exception of its gain factor) by the locations of the poles and zeros of its transfer function on the complex p plane (Fig. 2). Thus from a knowledge of the pole and zero locations of a transfer function

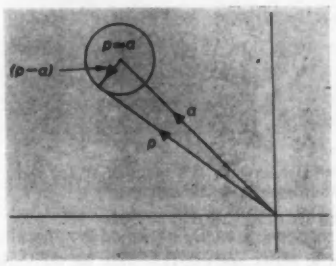


Fig. 3 A contour in the p plane around the pole at $p = a$

it is possible to obtain the shapes of the discontinuity response of the corresponding linear system, the frequency response, and indeed, the response to any arbitrary input.

As an example, a graphical method of obtaining the frequency response from the locations of the poles and zeros of a function will be described.

When $p = j\omega$, the magnitude and phase angle of factors of the form $(p - z_r)$, $(p - p_t)$ can be found for any particular value of ω (see Fig. 2) by measuring the length of the vector $|p - p_t|$ and its angle ϕ_t. Then the argument of $W(p)$ for that value of $p = j\omega$ is given by:

$$\arg W(j\omega) = \sum_{r=1}^{m} \phi_r - \sum_{t=1}^{n} \phi_t \quad \ldots (10)$$

and the modulus of $W(p)$ is given by

$$|W(j\omega)| = \frac{\prod_{r=1}^{m} |p - z_r|}{\prod_{t=1}^{n} |p - p_t|} \quad \ldots (11)$$

Thus, by finding the argument and modulus of $W(j\omega)$ for a number of different values of ω in this way, it becomes possible to plot a locus diagram on a complex plane representing the system frequency response.

It will be noted that poles and zeros close to the imaginary axis (i.e. having a small real part) have much more effect on

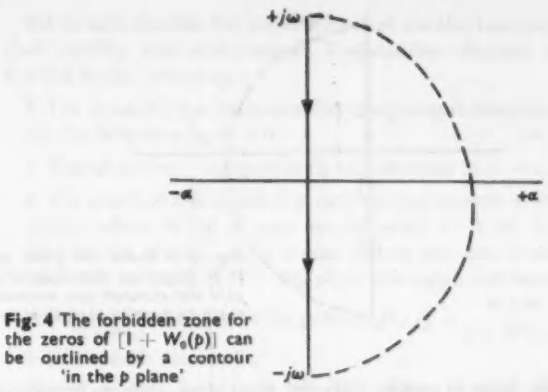


Fig. 4 The forbidden zone for the zeros of $[1 + W_o(p)]$ can be outlined by a contour 'in the p plane'

the frequency response than those well removed from the imaginary axis. This is because when $j\omega$ is equal to the imaginary part of such pole or zero, the relevant factor is reduced to a small real part only. Thus a mainly imaginary pole produces a large peak in the frequency response, and a mainly imaginary zero produces a large dip.

In order to emphasize the importance of closed-loop pole and zero locations, and particularly pole locations, in determining stability, we state the impulse response of a system* having one zero and two poles.

$$\text{Let} \qquad W(p) = \frac{K(p - z_1)}{(p - p_1)(p - p_2)}$$

Then the response to unit impulse is

$$K\frac{p_1 - z_1}{p_1 - p_2}e^{p_1 t} + K\frac{p_2 - z_1}{p_2 - p_1}e^{p_2 t}$$

and this response is stable only if both p_1 and p_2 have negative real parts. Stability is independent of the sign of z_1. (We ignore the cases $z_1 = p_1$, $z_1 = p_2$ as being trivial.)

Nyquist's criterion of stability

Consider a function $W(p)$ which has a pole at $p = a$, and

$$\text{let} \qquad W(p) = \frac{B(p)}{A(p)} = \frac{B(p)}{(p - a)\,A_1(p)}$$

Now consider a contour in the p plane consisting of a small circle around the pole of such small radius that it does not encircle any other poles or zeros of the function $W(p)$; it can be seen that on traversing the circumference of this circle once in an anticlockwise direction the argument of $W(p)$ decreases by 2π owing to the increase of argument of the vector $(p - a)$ by 2π, whereas the argument of $B(p)/A_1(p)$ is unchanged. (See Fig. 3.)

It is unnecessary to specify that the contour be circular. Any closed contour will suffice provided that it encloses no poles or zeros of $W(p)$ except the one at $p = a$. If the contour

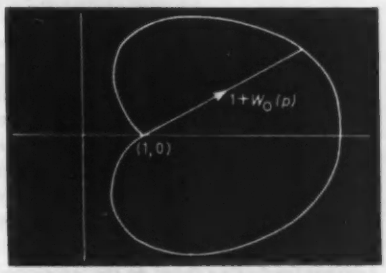


Fig. 5 This diagram on the complex plane is obtained by plotting the locus of the vector $[1 + W_o(p)]$ as p traverses once positively round the contour of Fig. 4

* The impulse response can be worked out using the classical method as outlined in Part 3 or by using transformational calculus as shown in the appendix.

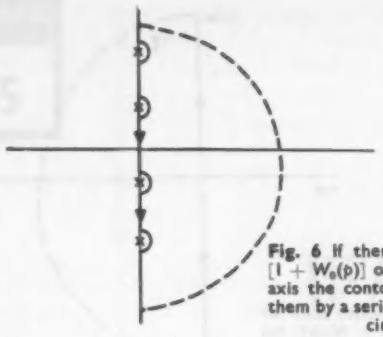


Fig. 6 If there are poles of $[1 + W_o(p)]$ on the imaginary axis the contour can exclude them by a series of small semicircles

be made to enclose a zero of $W(p)$ alone, then on traversing the contour anticlockwise once the argument of $W(p)$ increases by 2π. It is apparent that these changes of argument are unaccompanied by any change in modulus. In short, if a p plane contour encloses P poles and Z zeros of the function $W(p)$, then on traversing the contour once in an anticlockwise direction the argument of $W(p)$ changes by $2\pi(Z - P)$.

This is a result which we will now use to prove Nyquist's criterion of stability.

We have already seen that a linear system is stable if the roots of its characteristic equation have negative real parts. These roots form the poles of the closed-loop transfer function (assuming that the system is a feedback system) since the characteristic equation is

$$a_n p^n + a_{n-1} p^{n-1} + \ldots + a_0 = 0 \qquad \ldots (12)$$

(compare with equation 9).

For a feedback system we may write (see Fig. 1)

$$W_c(p) = \frac{W_1(p)}{1 + W_1(p)\, W_2(p)} \qquad \ldots (13)$$

where

$W_1(p)$ is the forward path transfer function.

$W_2(p)$ is the feedback path transfer function.

$W_c(p)$ is the closed-loop transfer function.

$W_o(p) = W_1(p)\, W_2(p)$ is the open-loop transfer function.

Now the poles of $W_c(p)$ are the zeros of $[1 + W_o(p)]$; hence a sufficient condition for stability is that the zeros of $[1 + W_o(p)]$ must all lie in the left-hand half of the complex p plane (i.e. have negative real parts), although there may be poles of $W_o(p)$ which lie on the imaginary axis or in the right-hand half of the p plane.

The forbidden zone for the zeros of $[1 + W_o(p)]$ can be outlined by a contour as shown in Fig. 4 (the dotted semicircle is intended to close the contour in an anticlockwise direction at infinity).

If now the locus of the tip of the vector $[1 + W_o(p)]$ is plotted for values of p obtained by traversing this contour once positively anticlockwise a new diagram is produced on the complex $W_o(p)$ plane. Fig. 5 is a typical example.

If there are poles of $[1 + W_o(p)]$ on the imaginary axis, let these be excluded by the contour in the p plane. This may be achieved by drawing a series of small semicircles round each pole as shown in Fig. 6. The semicircles must be small enough so that they do not exclude any other pole or zero.

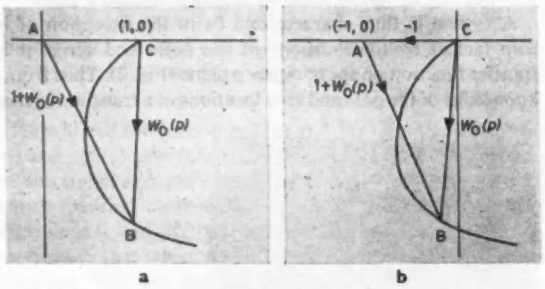
Then if P is the number of poles of $[1 + W_o(p)]$ inside the contour (excluding those on the imaginary axis), for one revolution of the contour in the p plane the locus of $[1 + W_o(p)]$ encircles its origin P times negatively, provided there are no zeros of $[1 + W_o(p)]$ in the right-hand half of the p plane or on the imaginary axis.

The locus of $W_o(p)$ can be obtained by shifting the origin as shown in Fig. 7. *Then for stability the number of encirclements of the point* $(-1, 0)$ *made by the locus of* $W_o(p)$ *must equal the number of poles that this function has in the right-hand half of the p plane.* This is a statement of Nyquist's stability criterion. If $W_o(p)$ has a pole in the right-hand half of the p plane, then the system is unstable on open loop. Since this rarely occurs, a simplified criterion for systems which are stable on open loop is commonly used and may be stated as: *A closed-loop system will be stable if the locus of* $W_o(p)$ *(called the Nyquist diagram) does not encircle the point* $(-1, 0)$.

It often occurs that a complete open-loop frequency response of a system is made up of

a the measured response of components which cannot be treated theoretically, and

b the calculated response of components whose behaviour can be accurately determined theoretically.



a b

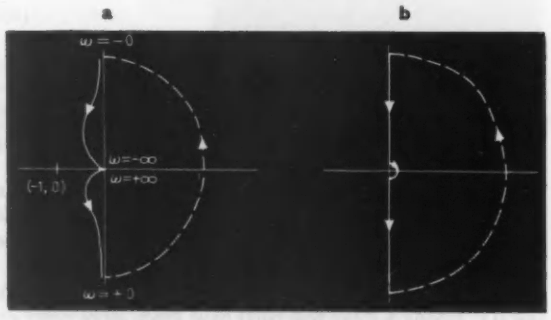
Fig. 7 These two diagrams show how the locus of $W_o(p)$ can be obtained by shifting the origin

Whilst the complete response is easily obtained graphically (particularly if logarithmic plots are used) it may be difficult or even impossible to obtain an analytical expression for it, quite apart from finding the roots of the expression in order to assess the system behaviour on closed loop. Under these circumstances the Nyquist criterion is particularly helpful in determining the stability of the closed-loop system.

We have already seen that encirclement of the point $(-1, 0)$ corresponds to true instability on closed loop.* If the open-loop response passes through the point $(-1, 0)$ we have limiting stability, and absence of enclosures of $(-1, 0)$ ensures stability. Evidently the closer the response locus of a stable system to the $(-1, 0)$ point, the nearer we approach

Fig. 8 The complete diagram for determining stability (a) and the p plane contour (b)

a b



* For a system which is stable on open loop

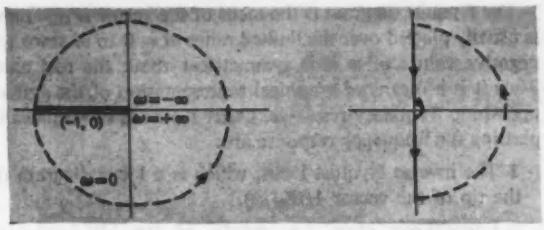


Fig. 9 A system with limiting stability and having an infinite peak in its closed frequency response

limiting stability and the more oscillatory become the roots of the closed loop. Hence we have an approximate indication of the 'degree of stability' without the necessity of knowing the poles of the closed-loop response.

The graphical relationship between open- and closed-loop response also can be shown on the Nyquist diagram. For the case when the system has unity feedback, i.e. $W_2(p) = 1$ in equation 8, we get:

$$W_c(p) = \frac{W_0(p)}{1 + W_0(p)} \qquad \ldots \quad (14)$$

The vector $W_c(p)$ can be found for each $W_0(p)$ by graphical division of $W_0(p)$ and $[1 + W_0(p)]$ (Fig. 7b).

Examples

A general form of open-loop transfer function may be written

$$W_0(p) = \frac{K}{p^l} \frac{\prod_{r=1}^{m} (p - z_r)}{\prod_{t=1}^{n-l} (p - p_t)} \qquad \ldots \quad (15)$$

Fig. 7b shows the case where $l = 1$, $n = 2$, $m = 0$ (see the simple position control system in previous articles), and we

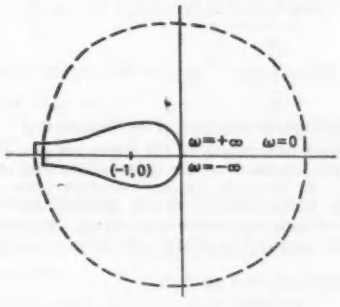


Fig. 10 The addition of a single lag or pole to the system of Fig. 9 makes it completely unstable

note that as

$$\omega \to 0 \quad \arg W_0(j\omega) = -\tfrac{\pi}{2}$$
$$\omega \to \infty \quad \arg W_0(j\omega) = -\pi$$

The system can never be truly unstable, but if we let $K \to \infty$ then $W_0(p)$ will pass very close to $(-1, 0)$ and the system will have limiting stability on closed loop and a very large peak in the closed-loop frequency response at the value of ω, giving a minimum value of AB $= 1 + W_0(p)$, i.e. $|W_0| \simeq 1$.

The complete diagram for determining stability is shown in Fig. 8a, the p plane contour being shown in Fig. 8b.

The fact that $l = 1$ means we have a pole at the origin, which must be encircled by a small circle at $\omega = 0$ in the p plane (Fig. 8a). This corresponds to the large semicircle in the W_0 plane (Fig. 8a). Thus the point $(-1, 0)$ is not encircled and the system is stable.

Let us now consider the possible types of transfer function, their stability and performance. The stability diagram is typified by the following:

1 The value of l (i.e. the number of integrations) determining the behaviour as $\omega \to 0$.

2 The value of $m - n$ determining the behaviour as $\omega \to \infty$.

3 The values of l, m, n and K in determining the path in the region where $W_0(p)$ is near to the point $(-1, 0)$, i.e. whether the point $(-1, 0)$ is encircled or not, and if not encircled, the value of $[1 + W_0(p)]$ in this region and hence the degree of damping of the poles of $W_c(p) = \dfrac{W_0(p)}{1 + W_0(p)}$

First consider values of l.

If $l = 2$, $m = n - l = 0$, we have Figs. 9a and 9b. Evidently the W_0 contour goes through $(-1, 0)$ for both positive and negative values of ω and the system is of limiting stability, having an infinite peak in its closed frequency response. Thus we have $W_0(p) = K/p^2$

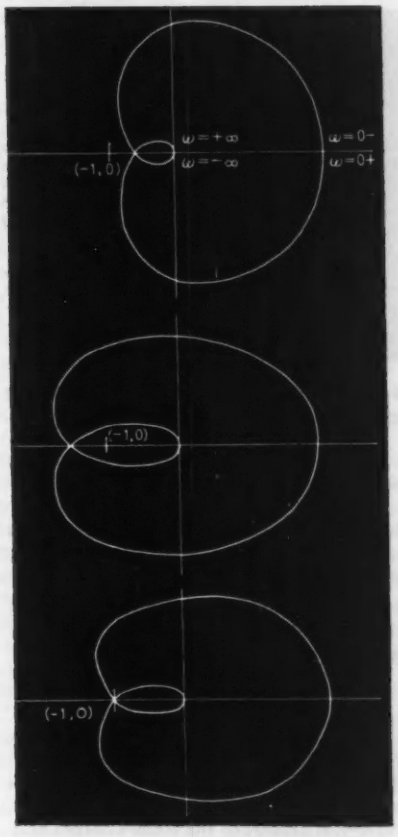


Fig. 11

a W_0-plane plot for a small value of K; the system is stable since the plot does not encircle the point $(-1, 0)$

b K is much greater and this system is unstable

c An example of a system with limiting stability

$$W_c(p) = \frac{\dfrac{K}{p^2}}{1 + \dfrac{K}{p^2}} = \frac{K}{p^2 + K}$$

and the poles of $W_c(p)$ are $p_1, p_2 = \pm j\sqrt{K}$; the addition of a single lag or pole gives

$$W_0(p) = \frac{K}{p^2(p - p_1)}$$

which is plotted in Fig. 10 and represents a case of complete instability.

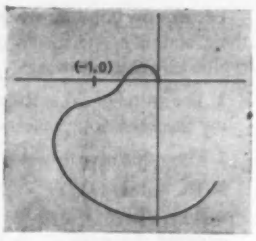


Fig. 12 The addition of a suitable zero to the system shown in Fig. 11c has the effect of making it truly stable

We need not consider cases where $l > 2$ since these are usually impractical.

Now consider a number of lags or poles only, giving a $W_o(p)$ of the form $K[(p-p_1)(p-p_2)\ldots(p-p_n)]^{-1}$. Let $n = 3$; then we have Figs. 11a, 11b and 11c.

Fig. 11a shows a W_o-plane plot for a small value of K. The plot does not encircle the point $(-1, 0)$ and the system is stable. Fig. 11b shows a plot where K is considerably greater, giving an unstable system. Fig. 11c shows a system with limiting stability.

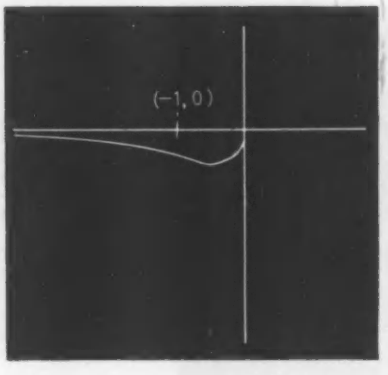


Fig. 13 The technique of adding a zero to obtain true stability can also be applied to the system of Fig. 9a

Now let us add a zero of such value that it has greatest effect when the magnitude of the original W_o is approximately 1.

$$W_o = \frac{K(p-z_1)}{(p-p_1)(p-p_2)(p-p_3)}$$

The result is shown in Fig. 12. The presence of the zero has improved the stability from limiting to truly stable, without the necessity of reducing the gain.

The same technique can be applied to the system having two integrations shown in Fig. 9a, giving Fig. 13, which again shows true stability instead of limiting stability.

Summary

The term 'transfer function' is introduced in this article and is used to replace the term 'vector multiplier' where the input is not necessarily sinusoidal. The transfer function, which is the ratio of the transform (Laplace) of the system output and input, is a function of a complex variable p.

The relationship between the open- and closed-loop responses is given by $W_c(p) = W_o(p)/[1 + W_o(p)]$ for a system with unity negative feedback.

The stability of a system on closed loop is determined by the poles $W_c(p)$ or the zeros of $[1 + W_o(p)]$, which must all be in the left-hand half of the complex p plane. This fact is used to prove the Nyquist criterion of stability (assuming that the system is stable on open loop), which states that:

A closed-loop system will be stable if its open-loop Nyquist diagram does not encircle the point $(-1, 0)$.

The Nyquist diagram is the locus of the vector $W_o(j\omega)$ and is usually plotted over the limited range $\omega = 0$ to ∞ since for negative values of ω it is symmetrical about the real axis. Thus it is a means of graphical representation of the system open-loop frequency response. Other methods of graphically plotting the frequency response are:

1 The inverse Nyquist locus, which is a locus diagram of the tip of the vector $1/W_o(j\omega)$.

2 Logarithmic plots, i.e. graphs of log $|W_o|$ against log ω and arg W_o against log ω.

The problem of choosing the form of open-loop transfer function $W_o(p)$ (number of integrations, poles and zeros as well as their respective locations) for the best performance subject to certain practical restrictions may be difficult. Techniques for solving this problem using frequency response diagrams will be described in later articles.

APPENDIX

Generalized Fourier transform

Let $x(t)$ be an arbitrary function of time: we shall then find the Fourier transform of $h(t)x(t)e^{-ct}$, where $h(t)$ is the unit step function.

Using Fourier's integral relationship we may write

$$\phi(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{j\omega t}d\omega \int_{-\infty}^{\infty}\phi(\tau)e^{-j\omega\tau}d\tau$$

Let $\phi(t) = x(t)h(t)e^{-ct}$

then $$\phi(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{j\omega t}d\omega \int_{0}^{\infty}x(\tau)e^{-c\tau}e^{-j\omega\tau}d\tau$$

Now write $p = c + j\omega$, whence $dp = jd\omega$. Then

$$\phi(t) = \frac{1}{2\pi j}\int_{c-j\infty}^{c+j\infty} e^{(p-c)t}dp\int_{0}^{\infty}x(\tau)e^{-p\tau}d\tau$$

Therefore $$x(t) = \frac{1}{2\pi j}\int_{c-j\infty}^{c+j\infty} e^{pt}dp\int_{0}^{\infty}x(t)e^{-pt}dt$$

Let $$X(p) = \int_{0}^{\infty}x(t)e^{-pt}dt \qquad \ldots (16)$$

$X(p)$ is called the unilateral Laplace transform of the function $x(t)$.

Whilst we have considered only functions $x(t)$ which are zero for $t < 0$, it is apparent that the Laplace transform exists for functions $x(t)$ which are not zero for $t < 0$. Since the Laplace transform takes no account of the value of the function for $t < 0$, it is apparent that the transform of $x(t)$ is identical with the transform of $h(t)x(t)$. Therefore, whilst the inverse Fourier transform is unique, the inverse Laplace transform is not unique.

The inverse Laplace transformation is given by:

$$x(t) = \frac{1}{2\pi j}\int_{c-j\infty}^{c+j\infty} e^{pt}X(p)ds \qquad \ldots (17$$

As with Fourier transforms, Laplace transforms can be used to solve differential equations. For initially quiescent systems

$$Y(p) = W(p)X(p) \qquad \ldots (18)$$

Thus we can state that the output response of a system is given by the inverse Laplace transform of the product of its transfer function and the transform of its input. It is not generally necessary to evaluate the integral of equation 17 in order to obtain the system response. Most input signals are zero for $t < 0$, and since no physical system can give a response before being stimulated, the output must be zero prior to $t = 0$. We may assume, therefore, that the inverse transform is unique, which enables the time function corresponding to the transform of the output to be identified from a table of transform pairs (often it may be necessary to split the function $W(p)X(p)$ up into a number of terms using partial fractions which can be identified separately).

For further information on transformation methods, reference should be made to Churchill's 'Modern Operational Mathematics in Engineering' (McGraw-Hill, 1944).

HOW TO APPLY PRESSURE CHARACTERISTICS OF LINEAR VALVES—2

by **P. D. BOYER, B.Sc.**
English Electric Co, Luton Airport

Servo errors due to jack friction

The performance of hydraulic servos, in the sense of minimizing errors, is more often than not severely limited by jack friction. Generally, an actuator with O-ring or similar seals exhibits fairly pure Coulomb friction at the velocities involved in following, the departures from the static value being no more than a few per cent. This friction value is usually high and as yet there seems to be no generally successful scheme for eliminating it. Although it can be substantially reduced by the use of dither, the power level is often prohibitive, resulting in general structural vibration.

The drift test

The magnitude of the jack friction in a servo is easily measured by employing pressure gauges to tap the pressures P or P_m (see diagrams overleaf). The servo amplifier balance control is used to vary the error. By this means the jack is made to drift slowly one way and then the other.

The gauges indicate:

In the 3-way test, P	*In the 4-way test, P_m*
$P = P_s/2 \pm \Delta P$	$P_m = \pm \Delta P_m$
Since	Since
$F = A(P - P_s/2)$	$F = AP_m$
$F_f/F_s = \pm 2\Delta P/P_s$	$F_f/F_s = \pm \Delta P_m/P_s$

where ΔP is the change in reading due to friction in the jack, F_f is the friction force and F_s the maximum stalled output force.

This value $F_f/F_s = p_f$ (p as defined overleaf) in both cases.

If transducers are used, the measurements can be extended, by using a triangular input waveform, to show variation of friction with velocity. Their use also makes possible the application of enough dither to activate the jack and the determination of what dither amplitude, if any, will decrease the jack friction sufficiently to be useful.

Reset error

The reset error ϵ_r is the maximum error which can arise in the static condition before the servo moves to correct it.

The insertion of the results of the drift test in the pressure-deflexion diagram, as lines $p =$ constant, shows what value of valve deflexion is required to initiate motion. In the simplest case, of no internal leakage in the system, the value of $\delta = X/U$ or $\gamma = X/X_{max}$ is given by the intersection of the p_f-line with the line $q_m = 0$. Since valve deflexion should be known in terms of error, the error required to initiate motion follows from this.

It can be measured directly in simple cases by 'zeroing' or locking the input and straining the output with an external load, first in one direction and then in the other. If the load is released gradually each time, the output will settle first on one side and then on the other side of the position it would take up if the reset error were zero. This demonstrates the reset band, of width $2\epsilon_r$. Although ϵ_r may be small compared with, for example, the steady-state velocity errors which can occur, it is often at least as important.

In the common remote position control servo, for instance, the error is large only during transients and the latter are critical only in relation to stability and settling time. Usually the servo is operationally effective only when the errors are small, implying low amplitudes and velocities or accelerations. In these circumstances the error due to friction is likely to be comparable with the steady-state errors of linear theory and is therefore usually very important.

It will be seen from the pressure output diagrams that if the valve is zero- or over-lapped, that part of the error due to a constant friction level, namely $(\gamma)_{p_f} - (\gamma)_0$, will increase with velocity. If the valve is under-lapped, the friction error $(\gamma)_{p_f} - (\gamma)_0$ remains constant, but is in any case larger than for the zero-lapped valve. If the servo consists of a simple loop with one integration the steady-state velocity error is also obtainable from the pressure diagram. In all servos allowance must be made for the effect of any low-frequency response shaping between ϵ and X.

Deduction and measurement of the reset error in the ways described above may show two discrepancies. The first will be evident if there is friction in the servovalve itself. The latter should be suppressed at a dither level which will not affect jack friction, so selectively removing the contribution of valve friction from the direct reset measurement. The second discrepancy arises from the simplification assumed above, i.e. no internal leakage within the system. However, the effect of this is readily introduced and particularly apparent in the testing of actual valves.

Tests for servovalves

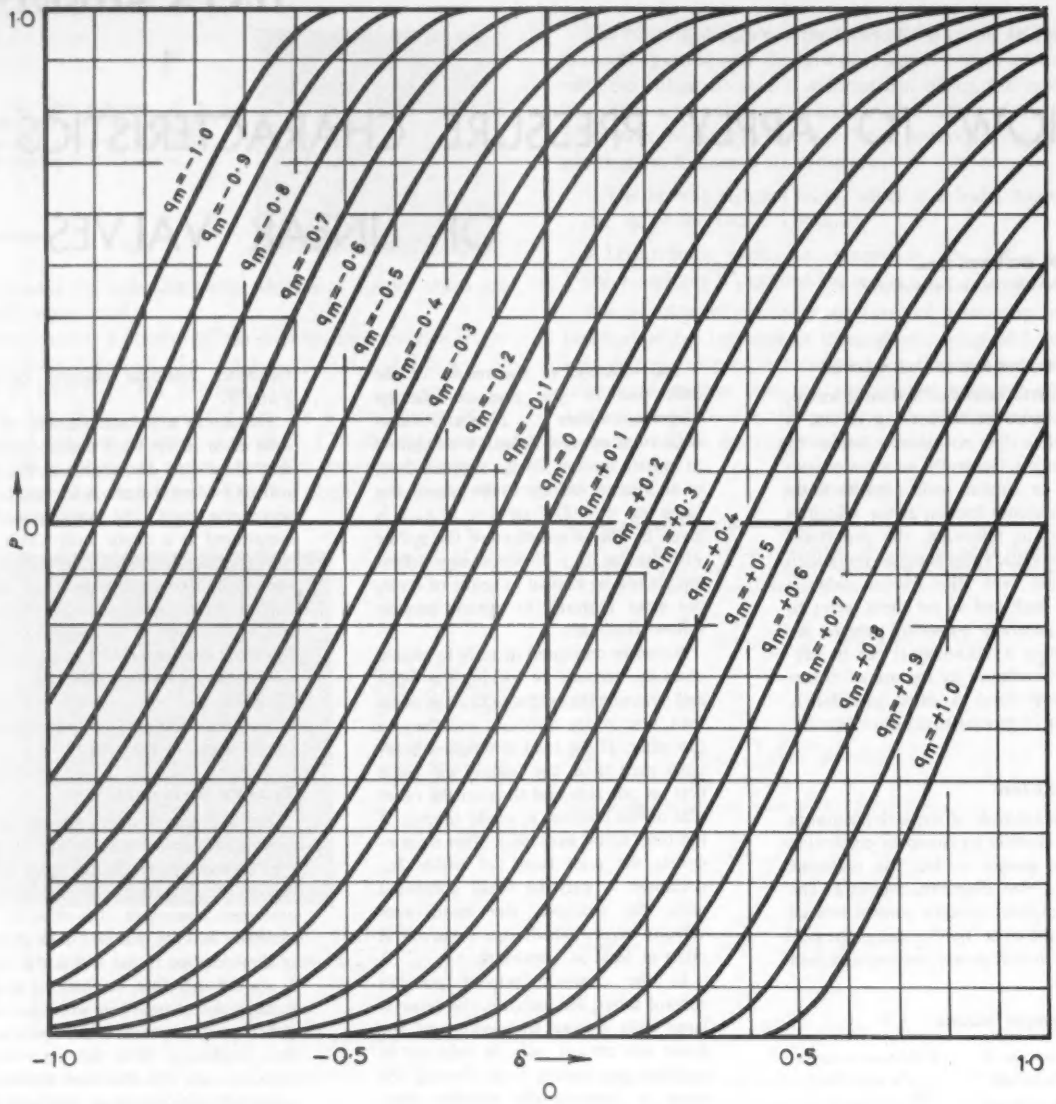
Pressure output tests have the virtue of simplicity and avoid the need for flow measurement in certain instances. While this is an advantage, particularly in hysteresis assessment, it is offset by the modified leakage patterns and absence of flow reaction forces within the valve. It should therefore be justified in any instance by comparison with the more difficult measurements under operational flow conditions. With this reservation, pressure tests give the reset sensitivity, hysteresis, threshold level, null shift and other parameters by a test method readily applicable in both oven and refrigerator, wherein instrumentation for flow measurement is either difficult or uncertain.

A four-way valve consists effectively of two three-way valves, and one aspect of valve pressure testing can be covered by a description of testing simple three-way valves. When this description is applied to four-way valves, P must be interpreted as P_1 or P_4.

The output port is blanked off except for a pressure tapping, which must admit no flow while an actual measurement is in progress. A plot of P against valve deflexion (which will have the same form as one of p against X/X_{max}) then provides, beside the reset error in conjunction with any given actuator, useful information about lap and leakage.

To be continued next month. See overleaf for theory of the fully underlapped valve, and reference curves.

DATA SHEET—5



THEORY OF THE FULLY UNDERLAPPED VALVE

Port area is assumed proportional to valve deflexion

Let U = Length of port opening in nominal zero position of valve.
X = Valve deflexion from nominal zero.
W = Total port width
$Q = C_q W 2U \sqrt{(P_s/\varrho)}$, the max. no-load flow
$\delta = X/U$
$q_m = Q_m/Q$

3-WAY

Put $p = (2P - P_s)/P_s$

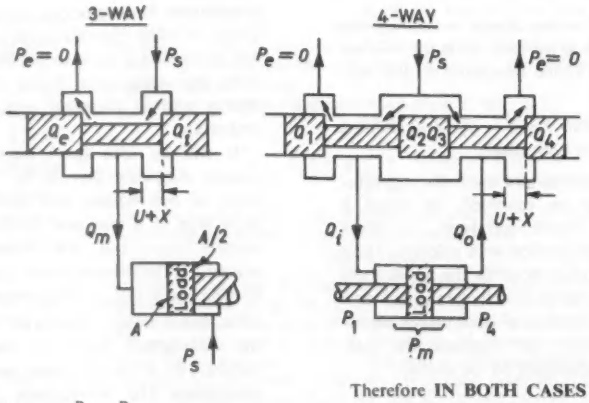
$$Q_m = Q_i - Q_e$$
$$= C_q W\{(U + X)\sqrt{[2(P_s - P)/\varrho]} - (U - X)\sqrt{2P/\varrho}\}$$

4-WAY

Put $P_m = P_1 - P_4$ & $p = P_m/P_s$

Then $Q_m = Q_i = Q_o$

$$Q_i = C_q W(U + X)\sqrt{[2(P_s - P_i)/\rho]} - C_q W(U - X)\sqrt{[2P_i/\rho]}$$
$$Q_o = C_q W(U + X)\sqrt{[2(P_s - P_o)/\rho]} - C_q W(U - X)\sqrt{[2P_o/\rho]}$$



Therefore $P_1 = P_2$

Since $P_2 = P_s - P_e = P_s + P_m - P_1$

$$2P_1/P_s = (P_s + P_m)/P_s = 1 + p$$

and $2(P_s - P_1)/P_s = (P_s - P_m)/P_s = 1 - p$

Therefore **IN BOTH CASES**

$q_m = \frac{1}{2}[(1+\delta)\sqrt{(1-p)} - (1-\delta)\sqrt{(1+p)}]$

If $p \leqslant \frac{1}{2}$, this is adequately represented by

$q_m = \delta - \frac{1}{2}p$

If $\alpha^2 = 1 - p \qquad \beta^2 = 1 + p$

$$\left(\frac{\partial p}{\partial \delta}\right)_{q_m} = \frac{2\alpha\beta(1 + \alpha\beta)}{2 - q_m(\alpha - \beta)}$$

On the δ axis, $\partial p/\partial\delta = 2$

Pick-off

by 'UNCONTROLLED'

I HOPE that the Education Committees of the 'Mechanicals', 'Electricals' and 'Chemicals' will soon do some hard thinking about control engineering. It seems that success in the new Dip. Tech. (Eng.) course in Instrument and Control Engineering at the Northampton CAT is unlikely to give a student complete exemption from any of the institutions' qualifying examinations, and in fact I am told that the course has not been framed to do this. However, it will surely be unfair on students gaining Dip. Tech. (Eng.)'s through this course or other similar courses that are started, if at the end of their studies they are expected to take endorsement subjects for the sake of gaining a professional engineering qualification. Moreover, it will be anomalous, since, as I understand it, all the other Hives Council courses in engineering are likely to give exemption from the relevant society's examination. Perhaps in time the Society of Instrument Technology will become a qualifying body and membership of it may then be the most appropriate professional qualification for control engineers. Meanwhile, I feel there should be room in the major engineering institutions for young well-qualified engineers with a 'generalist' outlook. This prickly question is naturally bound up with the present controversy over undergraduate education in control engineering, briefly discussed in CONTROL's leader last month.

SEEKING to escape for a few days from the world of instruments, I spent a short holiday on the South coast last month. The escape was not complete: in a largish Dorset hotel I found myself staring at a Bristol dual-pen circular chart recorder that indicated the temperatures of the outside air and of the hotel hall. The temperature bulb for outside seemed to have given up under the strain of this year's summer but the inside record showed a convincing path through the 'comfort zone' between 65° and 70°. I had not previously seen a temperature record of this type kept in a hotel. Is there an opportunity here for enterprising salesmanship? A temperature record may be an asset in keeping guests in a hotel contented, but I must say in this particular hotel no one beside myself ever appeared to look at the chart. The management too seemed surprisingly ignorant and apathetic about it, although I did discover from them that the chart was changed every Tuesday by the local clockmaker.

I FOUND myself at a lunch recently sitting opposite Mr A. G. Coaten, who is the Chairman of the Committee responsible for organizing the forthcoming Electronic Computer Exhibition and Business Computer Symposium. He told me that everything points at the moment to there being an excellent attendance at the Exhibition, with many visitors from abroad. There is much interest also in the Symposium, and two sessions of this—Sessions 1 and 6—are completely booked up. The others are filling rapidly. One revealing fact is that most of the applications for Symposium tickets come from individuals—rather than bulk applications from firms.

From the 24th to 27th November, just before the Computer Exhibition opens, the National Physical Laboratory is holding a Symposium on 'The Mechanization of Thought Processes'. It includes sessions on automatic programming, language translation, speech recognition, learning in machines, implications for biology, and implications for industry—a good medley of computers, cybernetics, control, and physiology which promises much exciting discussion. Many visitors from abroad who are attending this will be going on to Olympia. I gather that it has aroused much interest and that there is now a waiting list of people wanting tickets. The proceedings of the Symposium are to be published by the Stationery Office—probably in March 1959.

NOT long ago I noticed the UKAEA advertising for 'Technical Engineers' to work at Risley on fluid mechanics. An original classification indeed—but one that introduces a cross-current into the waters of confusion surrounding the meaning of the word 'engineer' in Britain, not forgetting the various specialized epithets used with it. I have met flying officers that do not fly and doctors who are not medical but the non-technical engineer has so far eluded me. Even the electrical engineer who is the Treasury's new Economic Secretary will find his knowledge of servomechanisms helpful when he considers trade cycles. Curiously the Risley advertisement called for their technical engineers to have an interest in engineering *science* (my italics), rather than technical knowledge of the subjects to be worked on. Let's hope some good hydraulic engineers turned up for the interviews.

I HEAR from Mr H. P. Kirk, Hon. Secretary of the Tees-side Section of the Society of Instrument Technology, that their Annual Dinner on 26th February 1959 is being attended by the President of the Society, Mr J. F. Coales. The other speakers will be Mr d'Leny, Managing Director of the Billingham Division of ICI, and Dr Ross, Managing Director of Elliott-Automation.

YOU cannot talk for long with someone about industrial control today before one of you emphasizes that designing autocontrol systems for existing plant is not really much good—the plant ought itself to be designed for autocontrol. Many people pay lip-service to this idea, but not enough plant and machinery is produced on the basis of it. Usually the control engineer has to marry his black boxes to plant originally designed for manual control. As the demand for integrated plant-and-control builds up, plant and instrument manufacturers will need to come together earlier over design. I believe that this will give rise to many more consortia and working arrangements between firms than exist at present. The instrument manufacturer who tries to provide control systems with all manufacturers of a particular industrial machine will bite off more than he can chew profitably. There is an analogy to this in the arrangements between digital computer and office equipment manufacturers.

'AUTOMATION in poultry farming is Mr Johnson's interest, and he has developed a machine which takes in several thousand live chickens every hour at one end and delivers them at the other not only dead but plucked, cleaned, washed and government-inspected'—*The Times*. I cannot say that I like the idea of this automatic machine, even if it does mean cheaper white meat, but its final action is impressive. This is surely the pinnacle of automatic inspection—programme control of the inspection equipment direct from Washington (yes, the machine *is* American).

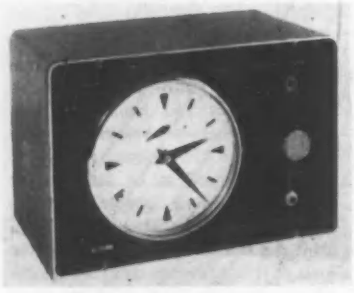
New for Control

A monthly review of system components and instruments

CRYSTAL CLOCK

completely transistorized

A recent transistorized crystal clock (type TSA 33) has been designed as a compact and portable standard frequency source of high accuracy. Completely transistorized, the equipment is housed in an attractive case, and incorporates plug-in stages and a high quality 50 c/s synchronous clock with a seconds hand. The internal clock can be omitted if desired and a 12 V 50 c/s synchronous motor can be supplied for external use. Switched standard output frequencies of 10 kc/s, 100 c/s and 50 c/s



High accuracy frequency source

are available, via a coaxial socket mounted on the front panel. The emitter follower output circuit incorporates series resistance to prevent damage to the final transistor due to accidental short-circuiting of the output. Provision can be made for mains, accumulator, or dry battery operation. The clock is made by Venner Electronics Ltd and the accuracy is within 1 sec per week operating in ambient temperature.

Tick **No 97** on reply card

TEMPERATURE MEASUREMENT

using d.c. amplifiers

Fielden Electronics Ltd have announced details of a new, reliable unit for temperature measurement using thermocouples. The equipment utilizes their series of d.c. amplifiers which are claimed to have an accuracy equal to the potentiometer methods commonly used in industry. The accuracy is 0·25 pc of range, with ranges up to 2½ mV or 50 deg C full scale. There is no current demand from the thermocouple, and the equipment is stable to variations in supply voltage of ± 15 pc. The unit operates off 12 V d.c. and can be powered from a small battery for long periods. There are a number of other useful features and the instrument is one unit of the Fielden 12 V d.c. Capacipoise system which will ultimately embrace transducers for all variables, multipoint indicators, recorders and controllers.

Tick **No 98** on reply card

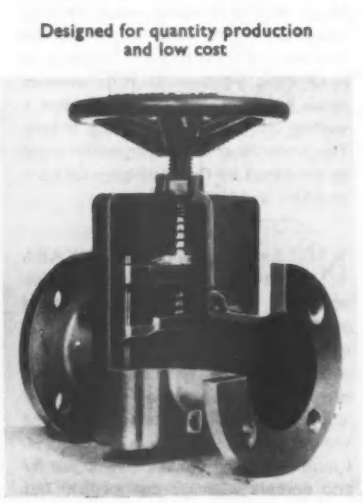
PINCH VALVE

with four grades of sleeve

The Rowe pinch valve has been particularly designed for quantity production and low cost. It is available in sizes from 1 in. to 3 in. bore diameter. It is claimed that, for the first time in this type of valve, die-cast construction has been used both for the casing and internal parts. At the same time, specially designed reinforced sleeves are used exclusively, all of which are suitable for internal pressures up to 100 lb/in². The robust aluminium alloy die-cast casing is split on its vertical axis for ease of assembly and servicing, and completely encloses the flexible sleeve and operating mechanism. The closing mechanism consists of two die-cast aluminium alloy anvils, a screwed spindle and a handwheel which operate to compress the sleeve equally from both sides. The screwed spindle has two right-hand threaded portions, the lower thread being twice the pitch of the upper section. The upper fine-pitch thread engages in a robust nut which is trapped in recesses formed in each half-casing, while the lower coarse thread engages with the rising bridge which is connected by two rods to the lower anvil. In turning the handwheel clockwise to close the valve it drops in a logical manner towards the top of the casing by a distance equal to one half of the valve bore, and in doing so provides a ready external indication of the position of the valve. At the same time, the coarse threaded section of the spindle causes the bridge and lower anvil to rise a similar amount to pinch the sleeve equally about its centre-line. The reinforced sleeves are available in four grades of natural or synthetic rubber materials: (1) for general-purpose duties; (2) for alcohol and milk; (3) for petroleum products, tar and ammoniacal liquors; (4) for abrasive materials.

Tick **No 99** on reply card

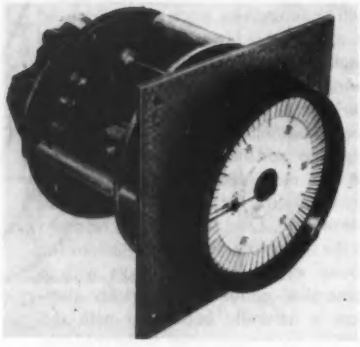
Designed for quantity production and low cost



SYNCHRONOUS CLOCK

useful aid in process control

A new synchronous clock with fully automatic reset has been marketed by Electrical Remote Control Co Ltd. The clock can be used for indication of elapsed time or



An electric clock with fully automatic reset

for the recording of the time taken for an operation, with starting and resetting control from a remote location. A variety of supply voltages can be provided. The clocks can be supplied with a motor and gear for full-scale indications from 30 seconds up to 120 hours.

Tick **No 100** on reply card

CENTRAL HEATING CONTROL

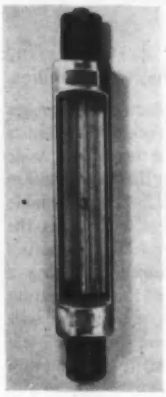
versatile, weather sensitive

The Stonebridge Electrical Co Ltd are introducing to their range of weather sensitive controls for central heating a new type which is designed for installations with two oil-fired boilers. There are two magnetic amplifier operated relays in the bridge system set differentially so that when the temperature out-of-balance is large, as

after a weekend shut down, both burners are operated, whereas for small drops in riser temperature only one burner comes in to maintain temperature. The control has a built-in clock unit with full day and night and weekend switching. Once set the control can be sealed and one of the following heating programmes selected by turning a switch which is the only external adjustment: (1) room temperature normal by day, reduced by night and at weekend; (2) room temperature normal by day, off by night and at weekends; (3) room temperature reduced by day and night; (4) room temperature normal by day and night; (5) set hot water temperature on boiler thermostat, automatic regulator off; (6) heating switched off.
Tick **No 101** on reply card

INDICATING FLOWRATOR
eliminates use of glands

The new Fischer and Porter indicating Flowrator (Model 2700) eliminates the use of stuffing boxes and packing glands by the use of rubber O-rings which seal the tube



Claimed to be of revolutionary design

ends to the metal end fittings incorporated in the metal body. The body is a robust assembly of mild steel pressings, obviating the need for bolts and screws. At its introduction the new Flowrator will come in two frame sizes; these will allow 10 : 1 ranges to be provided from maxima of 3–30 cm³/min air and 0·35–3·5 cm³/min water, to maxima of 4–40 s.c.f.m. air and 50–500 i.g.p.h. water. A third size of meter frame will shortly become available to accommodate flows up to 17–170 s.c.f.m. air and 200–2000 i.g.p.h. water.
Tick **No 102** on reply card

PERMANENT MAGNET MOTOR
smallest in Pullin range

The 08.PM is the latest addition to the Pullin range of international size d.c. permanent magnet motors. This is now the smallest motor in their range. The motor can be supplied for operation on 6, 12 or 28 V d.c. and will provide up to 4 W output under severe conditions. It is also available as a rate feedback tachogenerator. The no-load speed is 8000 r.p.m. and the stall torque 170 g-cm. The maximum efficiency is over 40 pc.
Tick **No 103** on reply card

THERMAL SWITCH
remote location of element

A new electronic thermo-switch is designed to maintain temperatures at a preset value, and gives immediate relay action for any tendency to deviate from this value. A variation of temperature will result in the platinum sensing element producing a signal in the electrical bridge network, the phase depending upon the sense of the temperature change. The signal is then amplified and applied to a phase sensitive detector which operates a heavy duty control relay, making or breaking, according to whether the measured temperature is lower or higher than the preset position on the control knob. The switch is available for use in the — 200 to + 500 deg C range and is manufactured by A. M. Lock & Co Ltd.
Tick **No 104** on reply card

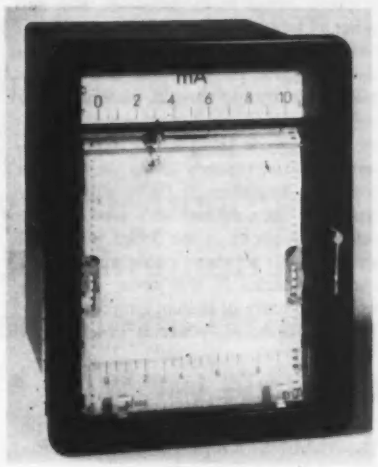
AIR COMPRESSORS
small, high performance

Three new compressors have been introduced by Alfred Bullows & Sons Ltd. They were designed to meet the needs of dentists for a small, high performance, silent and reliable compressor to operate air turbine driven drills; but the manufacturers are of the opinion that they will also have many industrial applications. One of the compressors, the Hydrovane 2AR30IE, has a rotary air compressor driven by a 1/3 h.p. electric motor rotating at 960 r.p.m., wound for 220 V a.c. 50 c/s. The air is controlled by a pressure switch which has a range of 35–40 lb/in². The other two compressors are similar to the first except for a few modifications.
Tick **No 105** on reply card

A silent compact compressor originally designed to meet the needs of dentists

AMMETERS AND VOLTMETERS
accurate, recording pattern

A new range of Metrawatt recording ammeters and voltmeters is being marketed by Metrix Instruments Ltd. Models comprising up to six channels, a.c. (15–500 c/s)



This recording ammeter can be supplied with either an ink-pen or burned-track recording system

or d.c., in flush-mounting, projecting or portable patterns are available with any scale calibration from 250 μA to 25 A, or from 60 mV to 600 V f.s.d. A comprehensive range of shunts provides facilities for range extension. Scales with either end or centre zero can be supplied, and maximum and minimum contacts for the operation of control and warning equipment can also be incorporated. The accuracy of indication is ± 1·5 pc for scale and ± 2 pc for the chart and the response time is 0·6 sec. All models can be supplied with either ink-pen or burned-track recording systems. Both systems are interchangeable. The chart driving mechanisms have a manually adjustable gear unit giving three accurate chart speeds. Speeds of ¾ in/h, 2½ in/h and 4¾ in/h are normally supplied but speeds up to 1420 in/h are available if required.
Tick **No 106** on reply card

PHOTOCONDUCTIVE CELLS
cadmium and indium antimonide

The second of the range of cadmium photoconductive cells announced recently by Mullard has now been introduced. This new cell (type ORP11) is designed for end-viewing and has a circular sensitive element 12·7 mm in diameter. Its spectral response range extends from 0·5 to 0·8 micron, with maximum response in the yellow, red and near infra-red regions. The ORP11 has high sensitivity and current handling capacity, and will operate relays directly with no intermediate amplification. It is inherently robust and operates from a.c. or d.c. supplies.

Mullard have also introduced a new type

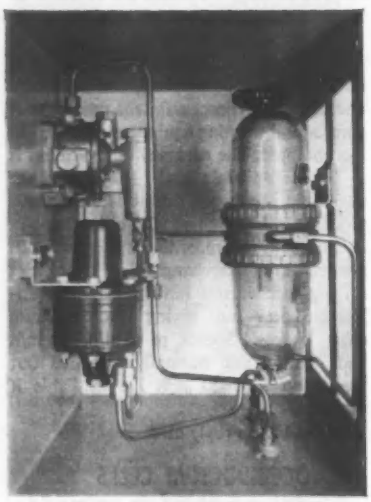
of photoconductive cell designed for high-speed infra-red spectroscopy, including the analysis of gases. The cell (type ORP10) has an uncooled indium antimonide element and is sensitive to infra-red radiations of wavelengths up to 8 microns. The indium antimonide cell is claimed to have a wider response range in the infra-red than any other type of detector operating at room temperatures, with the exception of thermal devices such as the bolometer and thermopile; these are too slow in response to be suitable for high-speed spectroscopy, whereas the response time of the indium antimonide cell is extremely short. The optimum scanning frequency to give satisfactory recording on a cathode ray tube, and to achieve simplicity in the design of the cell amplifier, is between 1 kc/s and 10 kc/s and frequencies of this order are easily within the scope of indium antimonide.

Tick **No 107** on reply card

LEVEL PACKAGE UNIT

leads to less piping

The Electroflo Level Package Unit can often be used where level measurement involves a purge system. The unit interconnects the standard purge pneumastat, miniature transmitter and air sets into one small panel; the gland plate of the panel terminates in three connexions for air



A unit which is finding wide application in the paper and sugar industries

supply, input from dip tube, and level signal output. With quickly fluctuating levels where remote, accurate, continuous measurement is required, this system, incorporating a locally mounted transmitter having a boosted output, has a number of advantages. It may be adapted to automatic control by using standard air-operated controllers. The package unit design is such as to reduce to a minimum the installation of piping on the site. It is finding wide application in the paper and sugar industries.

Tick **No 108** on reply card

COLD CATHODE TRIODE

subminiature by Hivac

A new subminiature cold cathode triode (type XC 23) has been put on the market by Hivac. The length of the unit is 48 mm and the diameter is 16 mm. The maximum continuous cathode current is 7·5 mA, the minimum anode breakdown voltage is 200 V, the nominal anode maintaining voltage is 67·5 V, and the nominal trigger breakdown voltage is 70 V.

Tick **No 109** on reply card

R.F. TRANSISTORS

more power dissipation

The Newmarket Transistor Co Ltd have announced an increase in the power dissipation of their V10 audio and V6 radio frequency transistors. The revised ratings given below are for a unit fitted with a clip fixed to a 3 in. square of 16 s.w.g. aluminium sheet. The ambient temperature is 25 deg C with a maximum junction temperature of 75 deg C. The maximum dissipation (mW) of the audio V10 series is 200, and that of the radio frequency V6 series is 125. The derating factor (mW/deg C) of the V10 series is 4·0 and that of the V6 series is 2·5.

Tick **No 110** on reply card

SCAMA

for redrawing instrument scales

For the last thirty years the Sensitive Research Instrument Co have been using a machine called Scama for hand-drawing their instrument scales, and the company has recently announced that the machine is now available for the commercial market. Scama is a hand-operated device for the redrawing of any flat electrical indicating instruments scale whose angular deflexion is no greater than 90°. It can be used for completely drawing or redrawing any part of a scale, of a standard or special-purpose instrument. Scama measures 18 × 18 × 14 in. and is supplied with all the equipment for drawing.

Tick **No 111** on reply card

MEASURING RELAYS

precise and sensitive control

Sensitact precision measuring relays, designed and developed by Brion Leroux et Cie, are now available in the United Kingdom and British Commonwealth from Leland Instruments Ltd. The relay consists of a galvanometer movement, complete with scale and pointer, to which has been added a moving contact. On each side of this are arranged two fully adjustable contacts which are instantly accessible beneath a transparent plastic dust-cover, and are adjustable over the full range of the scale. The relays are fully shielded, and are available in 16 different models, with moving-coil resistances ranging from 2·5 to 7500 ohms, and with full-scale deflexion current ratings ranging from 10 mA down

The fully adjustable contacts of this sensitive relay are accessible beneath a transparent plastic dust-cover.

to 0·02 mA. In the case of the most sensitive model, the minimum change of control power necessary to make or break contact is of the order of 0·05 mW. The relay contacts have a power-handling capacity of 200 mW. Each of the 16 models is available either as a maximum-minimum indicator with scale covering 90° and calibrated zero to 100 divisions, or in centre-zero form with scale calibrated 50 to 0 to 50 divisions.

Tick **No 112** on reply card

STRAIN GAUGES

with high sensitivities

Two new types of vibration strain gauges have been produced by Technical Ceramics Ltd. The gauges can be used in a wide variety of applications for the determination and analysis of dynamic strain. Available either as Expander or Bender elements, the gauges are made of Technical Ceramics grade 3 piezoelectric ceramic, having a wide temperature range of flat temperature coefficient. Piezoelectric material is self-generating and therefore requires less complex instrumentation than the wire strain gauge.

The Expander gauge consists of a strip of piezoelectric ceramic, silvered and polarized across the thickness dimensions, with the lower silvering carried round to the top to facilitate electrical connexion. Foil leads are provided. These elements have high sensitivities of the order of several hundred times that obtainable with wire strain gauges; the high frequency limit usually being determined by the structure under analysis.

The Bender gauge consists of a sandwich of thin piezoelectric ceramic and brass foil, responding to a bending movement. These are intended for mounting at a point of maximum bending, and owing to the construction can produce an output of over 1 V with a deflexion of 0·001 in. These gauges can be supplied with a high capacitance enabling analysis of low frequency vibrations.

In addition to the use of these ceramic gauges as vibration pick-ups, they may also be used to generate vibrations in a structure by application of alternating voltage to the transducer. At resonance a considerable displacement of the structure is obtained

Tick **No 56** on reply card for further details

From November 28 to December 4 on the IBM stand at the Electronic Computer Exhibition you will be able to see the most comprehensive range of IBM Electronic Data Processing Equipment ever assembled at one exhibition. But please don't imagine that **by themselves** these machines will solve all your business problems. Essentially we work **with** business, industry and government in the development of better management control techniques: the machines are simply tools for the job, and that's how we would like you to see the machines on Stand 34 at Olympia: as tools for the job. Your job, perhaps.

For the first time in Britain

305 RAMAC

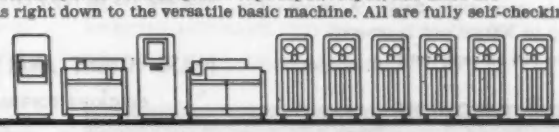
The newest concept in data processing since the electronic computer. The heart of the system is an array of spinning magnetic discs able to store up to *10,000,000* characters of information. Any record in this vast electronic ledger system can be referred to *at any time:* just type an enquiry and the 305 types the answer back. Fresh transactions are posted to the system *in any sequence*, calculations completed, documents printed or cards punched, and the file record updated—in *one* processing step.

DATA TRANSCEIVERS

Fast, reliable, and accurate transmission of data is essential to a centralized computing installation. With IBM Data Transceivers you can, *in a few seconds* send a punched card from branch to head office, or from continent to continent—by telegraph or telephone line or by wireless.

650 'TAPE' SYSTEM

This is the most widely used and the *most completely proven* computer in the world. We back that claim with 1,200 installed machines. The 650 on our stand is a very powerful system with magnetic tape input/output, but there are smaller systems right down to the versatile basic machine. All are fully self-checking.



421/604 — CALCULATING GROUP

If you have a computer type of job to do, but insufficient volume to justify one of the larger systems, the 421/604 may well be your answer—and an answer *at punched card prices*

IBM UNITED KINGDOM LIMITED
101 WIGMORE STREET, LONDON W1. TELEPHONE: WELbeck 6600

DATA PROCESSING · ELECTRIC TYPEWRITERS · INTERNATIONAL TIME RECORDERS

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CRCH

with a very low power input to the element. The transducers are so small that they do not materially affect the vibrational characteristics of the structure.

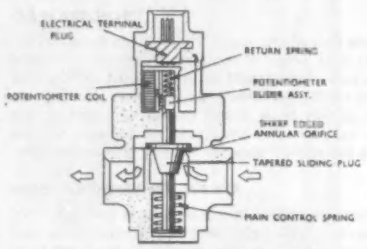
Tick **No 113** on reply card

FLOWMETERS

a range up to 300 gal/min

A range of flowmeters for use with a wide variety of fluids has been developed by the Gloster Aircraft Co Ltd. The flowmeters (type 101) were originally designed for high pressure aircraft hydraulic systems, but the new range is claimed to be suitable for the majority of fluids, from oil to toothpaste. The metering unit consists of a main body in which is housed a tapered sliding plug held in closed position in a sharp-edged orifice by a main control spring. Fluid passing through the meter overcomes the spring force, thus displacing the plug as a function of flow. Linearity is achieved with a suitable combination of initial spring load, spring rate and plug taper. The movement of the plug is transmitted to the indicator unit by means of a potentiometer (the slider being lightly spring loaded against the plug spindle), through a direct current balanced bridge network. The electrical supply is self-contained, power being obtained from two 1·5 V dry cells.

A means of calibration is incorporated in the circuit whereby the switching in of a resistance, equal to that of the potentiometer at the calibration deflexion, gives a rapid calibration check and calibration adjustment. An alternative method of transmission, using an induction pick-off, can be provided in place of a potentiometer which enables the flowmeter to be used with non-compatible fluids. A range of flows up to 300 gal/min is covered.



Suitable for most fluids, from oil to toothpaste

Tick **No 114** on reply card

ANEROID BAROMETER

accurate, portable, robust

A precision aneroid barometer has been developed by Mechanism Ltd to meet the need for a compact, portable and robust instrument with an accuracy comparable with that of a mercury barometer. It has a wide range of industrial, meteorological and surveying applications wherever measurement of barometric pressure is required. The instrument is calibrated for a range of 900 to 1050 mb, but this can be extended to meet special requirements. The accuracy of the instrument is ± 0·3 mb at 20 deg C and ± 0·5 mb at the extremes of the temperature compensated range of zero to + 40 deg C, and the sensitivity is such that changes in pressure of 0·1 mb can be discriminated. The mechanism is claimed to be more robust than a conventional aneroid instrument by virtue of the fact that the aneroid capsule is not required to drive a pointer through high magnification gears and levers. The capsule displacement is measured by means of a 1½ in. diameter drum micrometer graduated in mb at intervals of 0·1 mb. The point of contact between the micrometer and the capsule is detected by means of a miniature cathode-ray tuning indicator mounted integrally with the instrument and driven by small dry batteries located in the base. The closing of the contact circuit varies the voltage on the control grid of the indicator, causing a change in emission from the fluorescent-coated anode, which is observed as a change in the image. Detection of the point of contact by this method is extremely sensitive, a separation of about 0·00002 in. being sufficient to break the circuit. Battery life to be expected with daily usage is of the order of 12 months and long-term stability tests have shown that over a similar period of time no discernible drift in calibration was apparent.

The robust case conceals a precision aneroid barometer

Tick **No 115** on reply card

PULSE HEIGHT ANALYSER

employs computer techniques

The Marshall pulse height analyser (type HS100) was developed under a licence from the National Research Development Corporation. It is designed around the Hutchinson-Scarrott principle, employing computer techniques for the storage of information performed in a serial manner using two torsional acoustic delay lines.

The facilities include a visual display and automatic readouts in both analogue and digital systems. The analyser will accept a wide range of pulses of either sign up to a maximum mean counting rate of 1600 pulses per second. The input pulses may be back biased at the input to the amplifier, when a gate is provided for coincidence and anti-coincidence work. The memory is divided into either 100 or 150 channels for which the energy scale may be either linear or exponential, the latter case giving greater resolution at the lower energy end of a spectrum. This is a unique feature of the Marshall analyser.

Another facility is the ability of the instrument to subtract counts from a spectrum already in the memory. In conjunction with the live time integrator which is necessary at a high counting rate, the background count can automatically be subtracted from a spectrum, leaving the true count in the memory. A total count scaler records the total number of pulses analysed by the instrument.

The Marshall pulse height analyser has a number of unique and useful features

Tick **No 116** on reply card

PNEUMATIC CONTROL VALVES

heavy-duty, low price

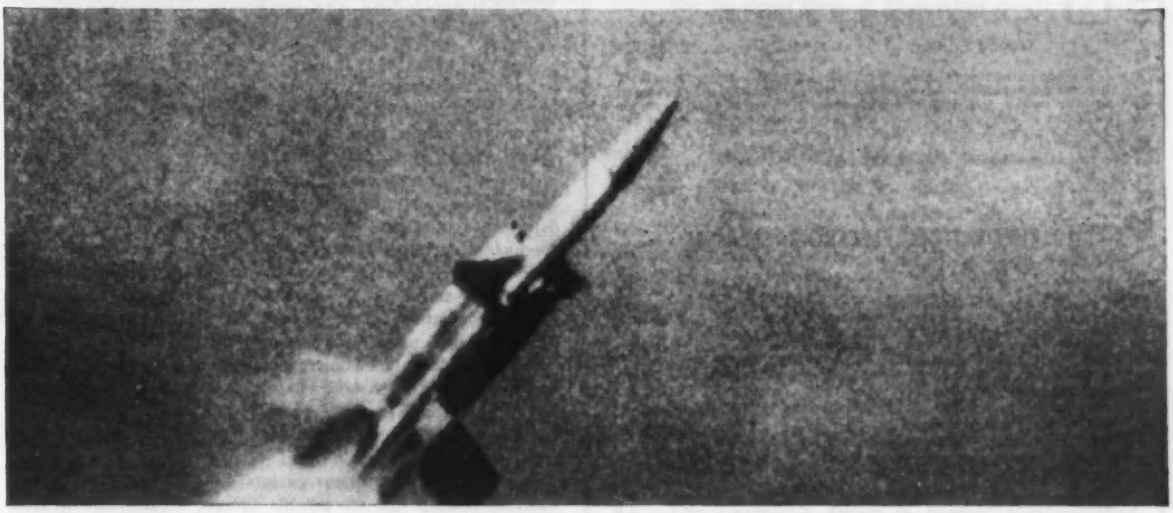
A new series of pneumatic control valves has been announced by Martonair Ltd. The heavy-duty valves are made in 3-port and 5-port forms, in ¼, ¾, and 1 in. BSP sizes. The four operating mechanisms—single pressure with air return, double pressure, lever with air return and three-position lever—are interchangeable between themselves and between different sizes of body. The prices are claimed to be extremely low and delivery is offered within a short time.

Tick **No 117** on reply card

Tick **No 57** on reply card for further details

MEMORANDUM ON MISSILE ENGINEERING

Is your future with the team that developed BLOODHOUND?



Adoption of Bloodhound by the RAF and now Sweden confirms Bristol's missile development team as the most successful in Europe.

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☐ **AUTOMATIC MEASUREMENT of QUALITY in PROCESS PLANTS**

Ed. SOCIETY OF INSTRUMENT TECHNOLOGY

1958 Price 50s.

These edited papers provide a valuable and objective survey of the various techniques available for quality control in process plants. The papers fall into two complementary groups; those covering a survey of the experience which has been gained with the wide variety of control instruments already in general use, while the second group explores the potential plant application of analytical techniques currently in use only in the laboratory.

☐ **PROGRAMMING for an AUTOMATIC DIGITAL CALCULATOR**

K. H. V. BOOTH 1958 Price 42s.

The availability, in rapidly increasing numbers, of electronic computing machines has meant the emergence of the new technique of preparing calculations for these machines, usually known as programming. This book contains some of the programmes which have been used on the "All-purpose electronic X-ray calculator" APEXC at Birbeck College, London.

. . . a good first introduction . . . THE ENGINEER

☐ **AUTOMATIC DIGITAL CALCULATORS**

A. D. BOOTH & K. H. V. BOOTH

Second Edition 1956 Price 32s.

A guide to the theory, design and use of automatic digital calculators. It has been prepared primarily for those using the machines as incidental to their studies, and detailed consideration is given to coding and the technique of preparing problems and programmes for this type of calculator.

. . . highly commended. THE ENGINEER

☐ **THEORETICAL ELECTROMAGNETISM**

W. R. MYERS 1958 Price 42s.

Provides a concise introduction to the essentials of electromagnetic theory, together with a few examples of its application. The book is designed for undergraduates reading for an honours degree in physics and the author assumes the reader to be familiar with electricity and magnetism up to the standard of Intermediate B.Sc., or Advanced level G.C.E. examinations. A selection of worked examples in electrostatics is given at the end of the book.

☐ **CIRCUIT BREAKING**

Ed. H. TRENCHAM 1953 Price 30s.

Circuit breakers are the key pieces of apparatus protecting electrical systems, and a knowledge of the problems involved and the most recent developments to solve those problems are of vital importance. The book gives a detailed account of the work on circuit breaking carried out by the British Electrical and Allied Industries Research Association (E.R.A.) whose Committee supervising the researches consists of specialist engineers representing manufacturing companies particularly interested in the work. Planned by E.R.A. with the practising design engineer, operating engineer and consultant in mind and also to provide a background of practical interest for the student.

. . . a valuable treatise . . . ENGINEERING

☐ **THEORY of ELECTRICAL MACHINES**

W. S. WOOD 1958 Price 50s.

A complete text in electrical machines suitable for final-year electrical engineering students. It treats the subject in a general fashion without departing from the conventional methods of analysis employing equivalent circuits and vector diagrams.

Though little attention has been paid to constructional detail and to pure design problems, an appendix on the fundamentals of design has been included, as such fundamentals have a contribution to make towards the understanding of electrical machines. M.K.S. units have been used.

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SELECTED BOOKS

Why only some uses of transistors?

***The Junction Transistor and its Applications** edited by **E. Wolfendale.** Heywood & Co. 1958. 402 pp. £4 4s.*

The control engineer might expect to find in such a comprehensively titled book at least a short section on the present state of the art of using transistors in control systems. Unfortunately he will be disappointed, for the book is, in fact, a collection of articles concerning only a few aspects of applications of junction transistors, and seems largely based upon Mullard reports which have appeared previously. For example, the important field of d.c. amplification is not even mentioned.

The work of nine contributors is included, and naturally the style and manner of presentation vary considerably. Also, since the sections are to some extent self-contained there is some overlap of subject-matter; the subject of transistor equivalent circuits, for instance, is treated, with minor variations, on four separate occasions. There is divergence of opinion between the authors at times: thus the author of the first section (Transistor Physics) states that the reverse leakage current of a germanium p–n junction will double for an 8° C rise in temperature, whereas the author of the next section maintains that 9° C is the correct figure. If the matter is put to test by an independent calculation by using the data and appropriate equations given in the book a figure of 7° C results.

However, despite such errors of detail, the book contains much valuable material. In particular the first two sections (Transistor Physics, and Characteristics) give a clear picture of the characteristics of junction transistors and also bring out the underlying dependence of these characteristics upon the physics of semiconductors: an approach whose value has only recently been fully realised. Other chapters deal with Equivalent Circuits, Biasing, A.F., H.F., and Class C Amplification, Oscillators, Modulation and Demodulation. These concern the bread-and-butter of the transistor world, namely, the sinusoidal market. These sections are, in the main, adequate, but are rendered rather tedious to read by the tendency of some of the writers to include each stage of the 'working out' of their algebra (surely unnecessary in a book of this standard), and also a plethora of numerical examples, again with each step in the calculations recorded in detail.

The chapter on non-linear circuits deals at length with some standard bistable and monostable circuits, binary counters and blocking oscillators, but digital computer techniques are not mentioned. Unaccountably the chapter fails to give any guide to what factors determine the response of a basic transistor circuit to pulse inputs, surely a matter of overriding importance with non-linear circuits. However in this case references are quoted for readers who wish to pursue the matter. The remaining chapters deal with d.c. converters and transistor measurements.

As the transistor compendium, which its rather ambitious name suggests, the book falls short of the mark. However, if the title is disregarded, one finds a good, although expensive, primer which should enable a newcomer to transistors to acquire a tolerable grasp of the more conventional applications. A. R. OWENS

Making networks—for nine guineas

***Network Synthesis, Volume I** by **David F. Tuttle, Jr.** Chapman and Hall. 1958. 1190 pp. £9 8s.*

This book is the first part of a comprehensive treatise on the synthesis of electric networks and the determination of their steady-state behaviour as a function of frequency. The fifteen chapters of the present volume, comprising more than a thousand pages, deal only with two-terminal networks; four-terminal networks are to be the subject of a second volume which is to follow. Classical network

theory is systematically summarized and extended; different methods of approach are compared; and a good deal of attention is given to methods for approximating to a desired circuit performance. The mathematical work is developed with adequate rigour and detailed proofs; and there is a considerable amount of helpful explanatory text which, however, tends to become discursive, lengthy and, at times, rather chatty in style. This explanatory matter could, with advantage, have been compressed and the bulk of the volume thereby appreciably reduced.

After a brief explanation of the scope of the book and of the properties of network elements, the mathematics of the complex frequency variable is introduced and followed by some energy considerations. Thereafter, the properties of driving-point immitance (impedance-admittance) are developed and applied in the first instance to *LC*, *RC* and *RL* networks; further generalizations lead to *RLC* circuits. Concluding chapters deal fully with various methods of approximation, such as Taylor series and the Chebȳshev polynomial and with the use of the potential analogy and conformal transformation. Appendices contain methods of computation and a bibliography of the subject.

The author states that the book evolved from the teaching of specialized postgraduate courses in network theory at Stanford University, California, and he is to be complimented upon the success with which he has achieved his object of preparing such a complete and authoritative reference book. Each chapter is liberally provided with problems for the reader to solve and thereby test his knowledge. Unfortunately, the author follows the usual American practice of omitting the answers, which makes the problems far less useful to the student than they would otherwise be. The paper, printing, layout and binding are excellent, but it is regrettable that the high price will put the book out of reach of those control and communication engineers who are most likely to be interested in the design of networks with specific frequency characteristics. They must be content to consult a library copy and they will be well rewarded.

B. HAGUE

Guidance without control

Missile Engineering Handbook *by* **C. W. Besserer.** *Van Nostrand. 1958. 614 pp. £5 9s.*

The series of handbooks entitled 'Principles of Guided Missile Design' achieved immediate success with the first in the series, entitled 'Guidance'. The succeeding books, while somewhat less spectacular, have served the purpose for which the series is intended, as reference handbooks. This latest in the series is intended to serve the system designer rather than the specialist. It contains basic data relating to nearly all phases of missile practice, from radar to propulsion engineering, and is compiled by a senior missile engineer. The information contained is in a readily accessible form for the engineer, but a reasonable amount of experience in the missile field is assumed. The data are particularly suited to the 'back of an envelope' phase of scheming new systems.

A notable and serious omission is the lack of data on control characteristics. This must be taken as a symptom of the difficulties of integrating control philosophy and missile system philosophy, but the omission could perhaps have been alleviated by some basic trend charts of accuracy against disturbance, bias and noise, which would assist in choice of bandwidth for the missile dynamics.

The book is written round American standards and British readers must therefore take care. The 'reflecting area', used in the radar range equations (Section 6) differs fundamentally from the British definition. A list of environmental test procedures and an extensive glossary of guided missile terms, while also based on American practice, are informative. Most scientists and engineers tend to think in terms of an idealized model of their problem. This book contains valuable reminders of the many aspects of the true problem, and should help in introducing a more mature and widely based design practice.

D. J. FARRAR

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Guidance

A. S. LOCKE. "The first comprehensive technical treatment of the key subject to appear in the U.K."—JNL. ROYAL AERO. SOCY. 741 *pp.*, 300 *illus.*, 94*s.*

The Algebra of Electronics *(in preparation)*

C. H. PAGE. Dr. Page aims to provide even the mathematically insecure engineer with the means for an intelligent understanding of electronics. *(Early 1959.)*

VAN NOSTRAND

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PEOPLE IN CONTROL

Mr F. J. Shields, Senior Technical Officer (Instruments) of BOAC, is joining Elliott Brothers as Service Manager, Aviation Division.

Mr Robert H. Dibb, Engineering Director of ICI Plastics Division, has been appointed Engineering Controller of ICI in succession to **Mr John E. Braham,** who has retired from the company.

R. B. Pullin & Co announce that **Mr R. W. Jelbart** has been appointed Sales Manager of their Thermostat Division.

Mr Leonard Baker has been appointed Deputy Managing Director of the Coventry Gauge and Tool Co. He has relinquished his directorship of Hamworthy Engineering.

Brig. L. L. Cross has been appointed Public Relations Officer of the Hawker Siddeley Group; he is retiring from the Army, after being Chief of Public Information at SHAPE since 1954.

Mr N. B. Brooks, Vice-Chairman of Richard Johnson & Nephew, has joined the Board of Keelavite Hydraulics.

The appointment is announced of **Mr F. J. Havenith** as Local Resident Director of the Belgian subsidiary company—Kent-Continental S.A.—of George Kent Ltd.

Mr G. F. W. Adler has been appointed chief mechanical engineer and a member of the directorate of engineering of Marconi's Wireless Telegraph Company Ltd, with responsibility for all mechanical engineering design aspects, both of Marconi's and its associated company, Scanners. He joins Marconi's from the English Electric Company, where he was chief development engineer.

Mr George Campbell has been appointed General Manager of the Chemical and Metallurgical Division of the Plessey Co. He was previously Technical Manager and Deputy General Manager of the company's Towcester plant.

Mr William Larke has accepted an invitation to be President of the Junior Institution of Engineers for 1958–59.

Metropolitan-Vickers announce the appointments of **Mr D. Hutton** as Assistant Superintendent, Switchgear Department,

GEORGE CAMPBELL

ROBERT H. DIBB

G. F. W. ADLER

J. N. TOOTHILL

and of **Mr V. D. Swain** as Assistant Superintendent, Control Department.

Mr J. N. Toothill has been made a Director of Ferranti Limited. He was appointed General Manager of the Edinburgh factory in 1942, which position he still holds.

LOOKING AHEAD

A diary for the next three months

NOV 24–27 — *The Mechanization of Thought Processes.* The Symposium will be held at the National Physical Laboratory, Teddington, Middx, in association with the Electronic Computer Exhibition at Olympia. Details by telephone from Mr D. V. Blake at the laboratory (MOLesey 1380, ext 27).

NOV 28–DEC 4 — *Electronic Computer Symposium & Exhibition.* See Preview in this issue.

JAN 12–14 '59 — *5th National Symposium on Reliability and Quality Control in Electronics.* See October p 166.

MEETINGS OF SOCIETIES

Junior Institution of Engineers. Details from The Secretary, Junior Institution of Engineers, Pepys House, 14 Rochester Row, SW1.

NOV 21 — *Printed Circuit Techniques.* P. A. Trigg.

Society of Instrument Technology. Details from The Secretary, Society of Instrument Technology, 20 Queen Anne Street, W1.

NOV 25 — *Digital Data-Recording for Nuclear Experiments.* R. C. M. Barnes.

DEC 10 — *An Experimental Approach to some Control Problems of Multi-Stand Rolling Mills.* H. Gill.

JAN 5 '59 — *Control Systems as Applied to Railways Signalling.* J. C. Kubale.

JAN 14 — *Symposium on Storage Media.*

FEB 11 — *A Digital Instrumentation System for use in the Testing of Jet Engines.* L. Airey.

FEB 24 — *Symposium on Automatic Weight Control in Industry.*

Royal Aeronautical Society. Details from The Secretary, Royal Aeronautical Society, 4 Hamilton Place, W1. Lecture on *Air Traffic Control over the North Atlantic.* E. W. Pike.

Institution of Electrical Engineers. Details from The Secretary, The Institution of Electrical Engineers, Savoy Place, WC2.

DEC 2 — *Power-System Automatic Frequency Control Techniques.* F. Moran.

DEC 16 — Discussion on *Modern Control Techniques on the Railways.*

JAN 6 '59 — *Silicone Electrical Insulation.* H. Davis.

JAN 26 — Faraday Lecture on *Automation.* H. A. Thomas. Tickets available during December on receipt of a stamped addressed envelope.

FEB 16–17 — *Specialist Discussion Meetings* on new digital computer techniques being arranged by the Committee of the Measurement and Control Section.

British Computer Society. Details from the Secretary, 29 Bury Street, SW1.

NOV 18 — *Use of a Computer in Industry.*

NOV 28 — *Latest Developments in Automatic Coding and Programming; Some Remarks about Automatic Programming.* Grace Hopper and J. Backus.

LOOKING FURTHER AHEAD

MAY 11–13 '59 — *Joint Symposium on Instrumentation and Computation in Process Development and Plant Design.* Organized by the Institution of Chemical Engineers, the Society of Instrument Technology and the British Computer Society. Details from the Institution of Chemical Engineers, 16 Belgrave Square, SW1.

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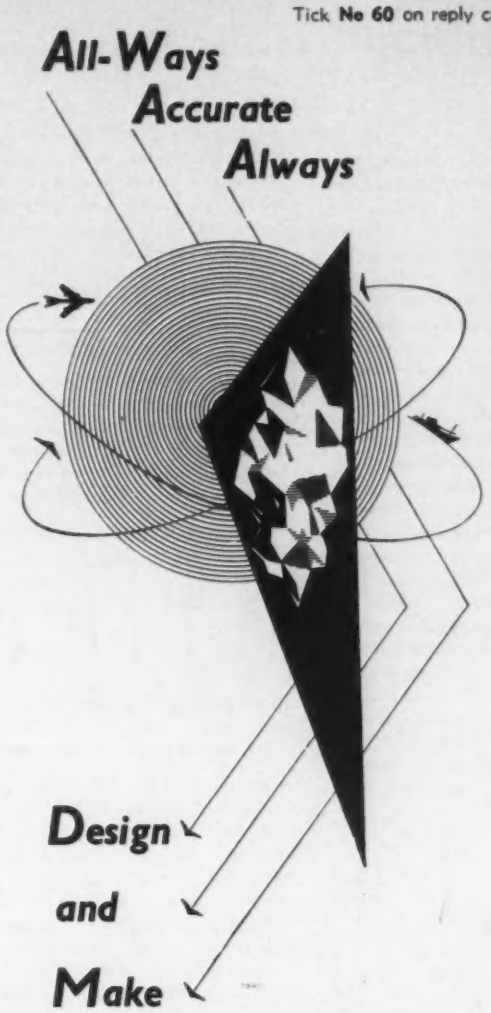

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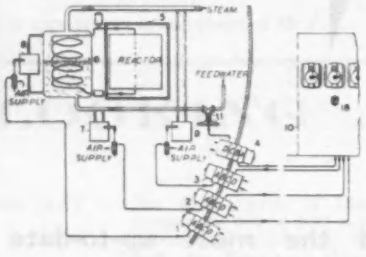
INVENTIONS

notes on recent patents in the control field

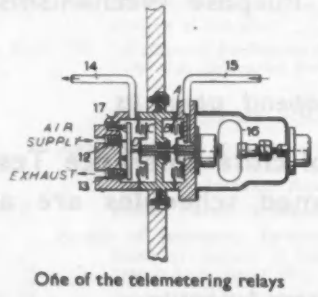
Telemetering relays

In certain industries it is required that signals should be transmitted, without loss of fluid, through the wall of a sealed container. The sealing is important where the fluid is radioactive and must be confined to the space within the container. Electrical signals may pass through fluid-tight vitreous seals in the walls but the patent is concerned with transmitting signals by fluid pressure. The signals are passed through telemetering relays in which the input pressure is separated from the output pressure by a number of diaphragms, in this way ensuring the complete sealing of the container. The diagram shows four telemetering relays (1, 2, 3, 4) installed in the wall of a container enclosing a nuclear steam-generating plant (5, 6). Three of the relays (1, 2, 3) transmit the readings from instruments measuring boiler feed rate (7), differential pressure (8) between two points above and below normal water level in the boiler, and steam flow (9). The readings are fed to an external panel (10) which sends a resulting inward signal through a telemetering relay (4) to an internal feed-water control valve (11).

The second diagram shows the body of the valve mounted in and sealing, an



The nuclear steam-generating plant is enclosed by a metal wall



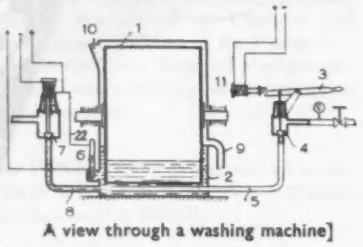
One of the telemetering relays

aperture in the wall. There are input (A) and output (D) pressure chambers sealed by flexible diaphragms. Between (A) and (B) are two more separate sealed chambers (B, C) through which passes a plunger connecting the two diaphragms together. At one end of the plunger is a lever which operates valves (12, 13) to control the pressure in chamber (D); in this way maintaining the pressure in the output pipe (14) the same as that in the inlet pipe (15). Two springs (16, 17) are provided to oppose the signal pressure. A manual valve (18) is used to replace automatic by manual control.

798 496. Fluid-pressure servomotor-control systems. **Bailey Meters & Controls Ltd.** 23rd July 1958.

Helping with the wash

In a method of laundering textile articles in a washing machine, fresh water is supplied for soaking, washing and rinsing, and the temperature during washing is automatically controlled by varying the fresh water supply whilst maintaining a constant



A view through a washing machine]

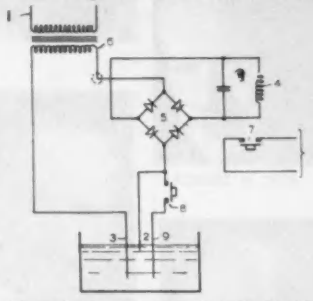
supply of heat at a temperature not less than that of boiling water.

In the diagram is shown a washing machine which comprises a perforated cylindrical drum (1) rotating in bearings inside an outer casing (2). To start the washing period a lever (3) is operated to open a valve (4) and admit steam into the washing liquid through a pipe (5). When the washing liquid reaches a predetermined temperature, further rise is prevented by a contact thermometer (6) which thereafter causes intermittent operation of a valve (7) to admit fresh water through a conduit (8), the overflow passing out of the machine through a pipe (9). In one arrangement, starting with rinsing water in the machine from a previous operation, more water is added by time switch operation of the valve (7) during a soaking period. The water is then shut off, the steam turned on and soap added through a funnel (10). When the predetermined temperature is reached it is maintained automatically during the washing period as described above. The steam supply is finally shut off by a time switch operation of a release solenoid (11) for the lever (3), and water is supplied again for rinsing purposes by time switch operation of the valve (7).

799 788. Automatic temperature control systems. **E. Sulzmann.** 13th August 1958.

Level control

In this floatless type of level control system an alternating current is passed through the liquid and used to regulate a pump supplying the liquid to the system. From the diagram it can be seen that the path of an a.c. supply (1) is completed when the level of liquid in a metal container rises



The relay is actuated when the liquid level rises to touch the electrode (2)

to make contact with an electrode (2), in this way energizing an electromagnetic relay (4) through a rectifier (5) and a transformer (6). The closing of the relay contacts (7) starts an electric motor driven pump (not shown) which draws liquid from the container, and the closing of another set of contacts (8) ensures that liquid is drawn off until the level falls below the lower end of the electrode (9). The electrode (3) may be replaced by the metal stem of the pump or the metal container. The electrodes can be made telescopic to help in selecting different levels of liquid.

798 212. Automatic liquid level control systems. **Broadwell Engineering Co Ltd.** 16th July 1958.

IN BRIEF

A system for measuring low rates of flow comprises a flowmeter, a fine control valve, a connexion between the inlet side of the meter and a source of pressure, a connexion between the outlet side of the meter and the fine control valve, the outlet of which is open to the atmosphere or is connected to a low-pressure part of the system and a connexion between the outlet side of the meter and a receiver. As applied to apparatus for finding the position of a leak in a sheathed cable, the distance of the leak from either end of the cable may be found by knowing the flow rates at each end.

800 005. Measuring flow rate. **Southern United Telephone Cables Ltd.**

In a valve for gases or liquids, particularly for fire mains, a resilient sleeve of rubber is inside, and clamped at each end of the valve body. The sleeve is pinched against a fixed streamline core within the sleeve by a cylinder which is moved axially by a handwheel. As the cylinder is withdrawn the pinching of the sleeve is eased, allowing it to expand and passing fluid through the valve body.

800072. Valves. **Vickerys Ltd and Harding, E.**

These abstracts are made from British Patent Specifications with the permission of the Controller of Her Majesty's Stationery Office. Complete specifications can be obtained from the Patent Office (Sales Branch), 25 Southampton Street, London, WC2. Price 3s. 6d. a copy (including postage, inland and abroad)